DENDROCHRONOLOGY AND THE STUDY OF CRANNOGS

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The dendrochronological potential of wood from two crannogs was evaluated. Consisting predominantly of non-oak species with fewer than 50 year-rings, the assemblages required the development of new techniques and approaches.

The problem of validating cross-matches between short ring sequences was resolved by a new methodology based on internal consistency. A group of internally consistent sequences contains no conflicting chronological relationships in the full set of its pairwise correlations. The SORT.STRING program, designed to identify sets of internally consistent groups in large data-sets, was tested on two ´known´ data-sets. It successfully identified the correct chronological relationships in these data-sets. Applied to the assemblages from the crannogs, it identified small, mutually exclusive groups of sequences which could not be satisfactorily merged to form a site chronology. Reasons for this are explored and indications for future work identified.

The dendrochronological potential of alder (*Alnus glutinosa*)was examined and a suitable methodology developed. Cross-correlation and chronology formation are possible but extreme ring-width values, i.e signature years, and compression of the outermost rings were identified as problematic features.

Evidence for woodland management practices in the crannog assemblages was evaluated. A model for woodland management was formulated, on the basis of two samples of modern coppiced material. This distinguishes between adventitious and formal coppice. Application of the model to hurdles found on the Irish crannog indicates that they are the products of adventituous coppice.

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CHAPTER 1 INTRODUCTION

Crannogs are artificial islands, built close to loch and river shores, using stones, organic debris and wood. They have often remained partly or wholly submerged since their construction thus ensuring a remarkable degree of preservation of organic material, and especially wood, on these sites. Stored in the growth-rings of the wood is information of value to archaeologist and environmentalist alike. The growth-rings of a tree contain information on its _in vivo_ micro- and macro-environments, on the manner of woodland exploitation practiced by the crannog-builders, and on the construction date and subsequent structural history of the crannog itself. This potential reservoir of information remains virtually untapped and it is the purpose of this thesis to assess the possibilities and limitations of the data available and to examine suitable methods of analysis. Two areas of specific interest to the archaeologist have been selected for this assessment, _viz_; site chronology and woodland exploitation.

Two crannogs, currently under excavation, provided the opportunity for extensive sampling of suitable timbers. Moynagh Lough crannog in Co. Meath, Ireland lies in a tract of marshy ground, the former bed of the lake that once surrounded the crannog but which was drained in the last century. The site is dated, on artefactual evidence, to the 8th century AD, during the Early Christian Era in Ireland. Oakbank crannog lies c. 30m offshore in Loch Tay, Perthshire, Scotland. It is wholly submerged, the top of the crannog lying 1m below the surface of the water. Radiocarbon dates place it in the mid-1st millennium BC.

The dating of timbers by means of their growth-rings is by now well-established (Baillie, 1982; Schweingruber, 1988). The width of each growth-ring is measured and plotted on a graph. The resultant tree-ring sequence, or curve, is then compared visually with another and the position of best match found. Most dating exercises begin with the comparison of sequences from the same context or site. A site-specific chronology is constructed which can often provide the archaeologist with data on the history of the site´s structures, indicating, for example, phases of repair and renovation, and length of occupation of the site. This is a **relative** dating exercise in that the constituents of the chronology are dated relative to each other but are not fixed absolutely in time. However, the construction of a site chronology is a necessary preliminary to its **absolute**, or calendrical, dating. The constituents of the site chronology are combined statistically to form a master chronology which is then compared against a calendrically-dated reference chronology. The site master is absolutely dated if a position of best match is found which is acceptable both visually and statistically.

The only dendrochronological work to date involving crannogs is that carried out by Baillie (1979) on Northern Irish crannogs. He was concerned specifically with the construction of a long reference chronology for Northern Ireland and was interested in the crannogs as repositories of long oak sequences which might extend the reference chronology back in time (Baillie, forthcoming). Consequently, although the timbers and, by implication, some phase of crannog occupation, are calendrically dated, nothing is known about the constructional history of the crannogs, nor about the position of the dated timbers within the period of the site´s use. One aim of this thesis is to construct site-specific chronologies for both crannogs, to provide the archaeologist with data on their constructional history. This is not as straightforward as it may seem. Existing techniques of tree-ring analysis have, in general, only been applied to oak sequences of 100 years or more. For this thesis I examined all the available exposed timbers on the crannogs and analysis of their species composition and age structure necessitated the development of new techniques and approaches.

I have also examined probable methods of woodland exploitation practiced in the environs of the crannogs. The seminal work of Morgan (1987) and Rackham (1977) on the Somerset Levels trackways has demonstrated that, given sufficiently large wood assemblages, reconstruction of management practices seems possible. Their results suggest that as early as the Neolithic period, the woodlands fringing the Somerset Levels were being coppiced. Management of woodland by coppicing is, in essence, a means of conserving an important resource and, it has been argued, was developed in response to the increasing scarcity of woodland as it was grubbed out to provide pasture and arable land for an expanding population (Edlin, 1978). The results from the Somerset Levels project therefore conflict with the perceived opinion that early settlers had unlimited supplies of primeval woodland available for exploitation. This raises the question as to why they began managing woodland at so early a date and whether it began as early in other parts of the British Isles.

Southern England certainly has the earliest documentary records of woodland management. Estate records of the early 13th century AD describe in detail a management system which came to be known as "coppice-with-standards" (Rackham, 1980). Contemporary estate records from Scotland do not refer specifically to coppiced woodland but the terminology of the documents is taken to imply as much. Thus, a charter, granted in AD 1250, allowed the Abbey of Lindores in North Fife an annual supply of hazel rods of different sizes from the

Perthshire woods (Lindsay, 1974). In AD 1289 the Abbey of Coupar Angus acquired lands at Inverack and Atholl in Perthshire by a charter which allowed the tenants to take "wands and rods" from the woodland. The tenants were required to enclose the woodland, a prerequisite of formal coppice management (Lindsay, 1974). However, apart from these few instances of management on monastic estates there does not appear to have been any strong tradition of coppicing (Lindsay, 1974). Edlin has suggested that coppice management was never developed in the Highland zone because of the availability of stone for house- and fence-building and because the pastoral activities pursued in the Highlands required less timber (Edlin, 1978). I have examined this argument by analysing the wood assemblage from Oakbank crannog in terms of woodland management. The approach formulated by the Somerset Levels workers was assessed for its suitability during the course of this research.

In Ireland there are documentary records contemporary with the crannog at Moynagh Lough which intimate that woodland was becoming scarce and that woodland management was being practiced (Kelly, 1976; O´Corrain, 1983). These are examined in some detail in Chapter 2 and the assessment of the wood assemblage from Moynagh Lough in terms of woodland management has been undertaken.

CHAPTER 2 THE SOCIAL AND ECONOMIC BACKGROUND

2.1 Introduction

One aim of this thesis is to examine the hypothesis that woodland was being managed by the occupants of Moynagh Lough during the early historic period and by the occupants of Oakbank crannog during the Iron Age. It is the purpose of this section to outline the social and economic background against which any scheme of management might have operated and to examine the extensive contemporary documentation (available only for Early Christian Ireland) for evidence that might support that hypothesis.

2.2 The Early Historic Period in Ireland

During the early historic period Ireland was a politically fragmented country with no central administration or organization. The basic political unit was the tuath or petty kingdom, a small area of land roughly the size of a modern Irish barony, or an English parish. For example the barony of Morgallion, in which the crannog of Moynagh Lough is situated is thought to have been a tuath some 234 sq. kms in area (Brady, 1983). The tuath was ruled by a king who was the independant ruler of his own petty kingdom. Below the king were, in hierarchical order, the nobility, the landed commoner and the landless servile classes, all usually of common ancestry.

"Custom and conservative tradition, acting within the boundaries of the tuath, were the agencies of order" (De Paor & De Paor, 1958, 74). These customs and traditions were embodied within a set of law tracts, generally known as the Brehon laws, which were originally orally transmitted, but were committed to writing during the 8th and 9th centuries AD by trained jurists (the brehons). The laws sought to regulate every aspect of life, from the property qualifications required for each grade in society to bee-keeping (Hughes, 1972). They portray an essentially rural society in which both nobleman and landed commoner were farmers.

Land was owned jointly by the extended family group but farming tended to be a co-operative venture between a group of neighbours (Hughes, 1972). Land was classified; there were three grades of arable land, three grades of uncultivable land and three types of pasture, the latter being arable after the harvest, fenced pasture and common land which was apparently common to the whole tuath (Mitchell, 1976, 178). The law tracts are not specific about the size of farms but Mitchell has estimated that a low-grade commoner farmed about 70 acres while the highest aristocratic grades farmed as much as 700 acres (Mitchell, 1976). Both tillage and stockraising were practised though it is not known in what proportions. A landed commoner is described as having equal numbers of cattle, sheep and pigs while his equipment includes a "full ploughing outfit with all its equipment..." (Byrne, 1967, 52).

The documentary evidence is complemented by the archaeological evidence. By far the most common class of monument for this period is the ringfort or rath, consisting typically of an earthen bank and external ditch enclosing a circular area, about 20-60m in diameter, within which there would be a single round-house (Proudfoot, 1961). It seems reasonable to interpret them as the homesteads of landed commoners.

It is estimated that there are between 30-40,000 raths in Ireland, of which only about 100 have been excavated. They are dispersed quite densely thoughout the landscape. In Co. Cavan there is approximately one rath to every 100 acres (Mitchell, 1976). In an attempt to estimate the size of the farm attached to the rath Proudfoot (1961) divided the available cultivable land in Co. Down between the number of known raths and calculated 40-80 acres, a figure not dissimilar to Mitchell's estimate (see above). Despite the survival of so many raths their field systems are rarely found. The tracts mention two kinds of land division which might be expected to leave traces, the ditch and its concomitant bank, and the stone fence (see below). The great majority of raths are situated in good arable land and, while many have been untouched by farming practices, mainly because of superstition associated with them (Estyn Evans, 1977), the slighter banks and ditches have probably been destroyed by the plough. A survey of raths in more marginal land on the fringe of the Antrim plateau has revealed a number with associated curvilinear fields enclosing areas of 0.2 - 2.0 ha (Williams, 1983).

The finds assemblages from the excavated raths certainly testify to cereal production and stockraising. Coulters, shares, sickles and reaping hooks, together with all the cereals mentioned in the tracts, wheat, oats, barley and rye, have been found (Monk, 1986). On most sites where bone has survived those of cattle predominate and analysis suggests that dairying, rather than beef production, was the chief concern. This contention is supported by the wide variety of dairy foods described in the law tracts (McCormick, 1983). Although cattle were all-important, a mixed husbandry was practised. On most sites pigs were second in importance to cattle and sheep form a small, but consistent, percentage of the total (McCormick, 1983, 255).

To summarize, the archaeological and documentary evidence jointly suggest a landscape that was, on the whole, densely settled, well-ordered and divided into privately-owned parcels of land, most of which was under arable or pasture. How does the woodland element fit into such a landscape? Against such a background it is certainly easier to imagine discrete areas of conserved woodland rather than large tracts of intact virgin forest. There are a number of contemporary texts which give some idea of the nature of the local woodlands.

A section of the Bretha Comaithchesa or "Laws of Neighbourhood", lists 28 trees and shrubs and enumerates the penalties for felling or damaging them and the compensation due to their owners (Kelly, 1976).

There were four categories of importance and the trees were ranked within these categories according to size, quality and usefulness. These are listed below;

NOBLE TREES	COMMONER TREES	LOWER RANKS	BUSHES
Oak	Alder	Blackthorn	Bracken
Hazel	Willow	Elder	Bog-myrtle
Holly	Hawthorn	Spindle	Gorse
Yew	Rowan	Whitebeam	Blackberry
Ash	Birch	Arbutus	Heather
Pine	Elm	Poplar	Broom
Apple	Cherry(?)	Juniper(?)	Rose(?)

(Mitchell, 1976, 177)

Oak is included for "its acorns and its dignity" whilst hazel is included for "its nuts and its rods", possibly a reference to coppiced rods (Kelly, 1976, 109). The inclusion of pine is curious because the pollen record indicates that it had all but disappeared in Ireland by AD200 (Mitchell, 1976, 177). Its value lay in "its resin in a bowl" (Kelly, 1976, 112), clearly implying living trees rather than bog pine. Its inclusion indicates, perhaps, the very early oral origins of the tract (ie, before pine became so scarce) or the local importance of the species.

Compensation for damage and destruction of trees and bushes was reckoned in terms of livestock, ranging from a milch cow for felling a Noble tree to a year-old heifer for the "extirpation" or destruction of a neighbour´s bush (Kelly, 1976, 121).

The law tracts tend to portray a highly idealised, schematic picture of early Irish society and the problem of interpretation is one of deciding how closely they approximate to reality. Many can be viewed as attempts by tidy-minded jurists to categorize and order everything in sight! Given that caveat, how is the existence of the tree list to be interpreted? The system of compensation clearly implies that some woodland at least was privately owned, possibly by the nobility, and the tree list could be seen merely as a guide for the protection of private property. However, it could also be seen as a recognition of the increasing scarcity of woodland and the necessity to protect the remainder by law. Certainly, the importance of woodland resources is recognised in the ranking of each species according to its economic attributes.

Another section of the Bretha Comaithchesa, describing the laws relating to fencing is also of interest in this study. Listed therein are descriptions of the kinds of fences appropriate to particular types of land, rules for their maintenance and the levels of fines to be imposed if they fell into disrepair enabling stock to trespass on a neighbour´s land (O´Corrain, 1983).
There were four kinds of land division, a ditch, a stone fence, an oak fence and a post-and-wattle fence. The first two types are self-explanatory. The latter was constructed of closely set stakes driven into the ground around which were woven three courses of bands of withies surmounted by a crest of blackthorn to prevent animals jumping over. The oak fence was constructed so "that the top of one tree should be on the bottom of the other tree and it is to be so made that

the oxen may not go through it because of its height nor the little animals because of its density" (translated in O´Corrain, 1983, 250). O´Corrain interprets this as meaning that a line of trees in woodland were partially felled so that they fell in a continuous, unbroken line but were still growing, possibly like a laid hedge. The oak fence was clearly for use only in woodland and it cannot be replaced by another fence type " for leaves fill up the ditch and trees break the stone wall". This can only mean that areas within woodland were being fenced off. In a woodland being managed as coppice, the enclosure of a recently felled area was essential to protect the new shoots from grazing animals (Rackham, 1976). It seems reasonable, therefore, to conclude that, in this tract, we have indirect evidence for the practice of coppicing.

In summary, Early Christian Ireland possessed all those features seen as pre-requisites for the introduction of a formal system of woodland management (see Chapt.7). Its population had risen dramatically, causing a rapid expansion of agricultural activity around AD300 (Mitchell, 1976, 166). Woodland dwindled as pasture and arable land expanded, prompting the enactment of laws to protect the remainder. However, apart from the tree list, the law tracts are remarkably silent about the management of woodland considering the attention they devote to most other aspects of rural life. Of course, it must be remembered that the law tracts are fragmentary and that the relevant text may simply be lost. We must look to the assemblages of waterlogged wood for an answer.

2.2 The Iron Age in Scotland

In describing the settlement and economy of Iron Age Scotland Cunliffe (1974) concentrates on two areas, the "Tyne-Forth province", which covers much of Southern Scotland, and "NW Scotland and the Islands". Both of these areas contain distinctive monument types which have attracted much archaeological research and sufficient sites have been excavated to provide a chronological framework and evidence, though somewhat scanty, on the economic base of the settlement. In the Highlands and Islands Iron Age archaeology is dominated by two peculiarly Scottish monuments, the broch and the dun, while in Southern Scotland the Iron Age is marked by a clear progression from palisaded enclosure to hillfort. Over 90% of Scotland's 1500 hillforts are concentrated in this area (Ritchie & Ritchie, 1981).

Oakbank crannog, in Loch Tay, Perthshire, lies on the Southern edge of the Central Highlands, bordering the Eastern plateau of the Grampians an area which has been neglected archaeologically, possibly because its monuments are more disparate and less impressive than those of the two areas described above. As a consequence dating evidence is scarce. Until recently there were no settlements of demonstrably Iron Age date in the region with the exception of the vitrified forts of the North-East which begin to appear c. 600BC (Ritchie & Ritchie, 1981). A group of monuments, similar in construction to the duns of the West are to be found in Central Perthshire and this similarity has attracted an Iron Age label for them although excavation has yielded no dating evidence. However, unlike the dun, they tend to be situated in indefensible positions, overlooked by higher ground and, for this reason, Stewart (1969) has preferred to class them separately, calling them "ringforts". They are strung out along the valley sides of Glen Lyon and are also found in Loch Tummel, Loch Rannoch and along the River Tay, but, surprisingly none are known along Loch Tay. In fact, prior to the Loch Tay survey (Dixon, 1982) the area appeared to be virtually unsettled during the prehistoric period (Stevenson, 1975). The density of crannogs in the loch now compares with the density of sites known further West along the valley of the River Tay. The recent surveys in Loch Awe and Loch Tay suggest that many of the Highland lochs may have their complement of , as yet, undetected crannogs and, given the cluster of mid-1st millennium BC dates that C14 samples from these crannnogs have produced, it would appear that, in much of the Highlands, the crannog may have been the only type of settlement in use in this area during the period.

In a landscape as diverse as that of Scotland it would be surprising to find a single economic response to the widely differing environments. However, information regarding the economy in the Iron Age is so scant that it is impossible to even hint at the possible diversity. In the acid soils that cover much of Scotland bone does not survive and where it does,as, for instance, on the calcareous sands of the Northern and Western Isles, the economy it represents there cannot be extrapolated to settlement in the rest of Scotland. Elsewhere the evidence for economic reconstruction consists of scraps, such as the presence of quernstones and a small number of carbonised grains of barley or oats, lists of animals represented by a few fragments of bone, all of which merely attest to the practice of both cereal cultivation and animal husbandry. At present the evidence is inadequate to facilitate refinement of the picture. For much of Scotland the crannog, with its well-preserved organic remains, is the only potential source of economic evidence, a source which remains virtually unexploited (see below).

Despite the variety in monument type across Iron Age Scotland there is an overall settlement pattern. With the exception of Southern Scotland where there is a tendency towards the agglomeration of settlement into larger hillforts, the pattern is one of dispersed settlement with isolated homesteads, crannogs, brochs and duns representing the defended homesteads of extended families. There is little evidence of large tribal groupings nor is there evidence of competition for land in the form of large-scale land division and enclosure as is seen in Southern Britain (again, Southern Scotland is the exception).

The pressure on land in Scotland came, not from an expanding population, but through the combined effects of topography and climate. The Iron Age saw the initiation of peat growth in many parts of Scotland, thus reducing the land available for agriculture and pasture. More importantly for this study, the topography of many of the Highland lochs is such that there is only a narrow strip of land between loch shore and mountainous slope available for settlement and cultivation. In the course of the survey of crannogs in Loch Awe the physical environment of the crannogs was also taken into consideration in order to determine the physical constraints on the crannog builders (Morrison, 1985). 17 of the 20 crannogs were located adjacent to patches of land that, prior to recent afforestation along the Loch, were used as arable land or classified as good quality meadowland (Morrison, 1985). Morrison concluded that the crannog-builders were more concerned about proximity to agricultural land than defence. Furthermore, by building the settlement offshore, the crannog-builders were freeing yet more of the restricted cultivable land.

How did woodland fit into this landscape? Using a general synthesis of Scottish vegetational history (Birks, 1978) and the composition and distribution of existing semi-natural woodland in Scotland (McVean, 1964) the woodland environment of Loch Tay can be reconstructed, if somewhat generally. Alder, with some willow, fringed the loch shore. A mixed deciduous woodland, predominantly oak with some ash, elm, birch and hazel, would grow on the lower slopes while on the steeper, higher slopes pine and birch would dominate. If land for agriculture was at a premium then the flattish strip along the loch shore would surely have been cleared of wood. Small pockets of woodland may have been conserved and managed to provide an easily accessible source for the crannog-dwellers but the proximity of plentiful supplies of wood on the lower slopes and the absence of any concentration of settlement does weaken the case for woodland management in Iron Age Scotland.

CHAPTER 3 CRANNOGS - THE ARCHAEOLOGICAL SETTING

3.1 Definitions

In common archaeological parlance, the term ´crannog´ is used to refer to any wholly or partly artificial island. A term that covers structures built in a wide variety of habitats, using a wide range of constructional techniques and inhabited over almost 2 millennia might be thought to be of little descriptive value but investigation of these structures has been so limited that a more detailed definition is not yet possible. Lynn (1983, 50) prefers to define them as "man-made island strongholds" but this implies a function that might not apply equally to all crannogs. For the same reason "lake-dwelling" is also inappropriate. Unlike most other archaeological appellations the term ´crannog´ was used by those who built and inhabited them (Munro, 1882). In Gaelic, the prefix ´crann´ means wood or wooden while the more specific term crannog, or crannag, can mean pulpit, prow of a ship, framework, wooden vessel as well as fortified island. The term was often applied to both artificial and natural islands (Lacy, 1983, 104) which tends to imply that, in its original usage, crannog referred to the superstructure i.e., the most visible part, and not to the method of construction of the substructure, as is often supposed.

3.2 A brief history of crannog studies

Scotland

At the turn of the 19th century large-scale land improvement schemes had resulted in the lowering of many lake levels (and, in some cases, the disappearance of the lake altogether), revealing large numbers of previously submerged crannogs. Many were "investigated", often by the landowners themselves, but, while the reports these investigations generated give us tantalizing glimpses of the wealth of information available, quantification is impossible, given their amateurish nature and restricted scope. A more serious academic interest was stimulated by the discoveries of similar lake dwellings in the Swiss Lakes in 1854. Keller´s **Lake Dwellings of Switzerland** was published in 1866 and included a report on Scottish crannogs by John Stuart, then Secretary of the Society of Antiquaries of Scotland. The first thorough and well-recorded excavation (by the standard of the day) was carried out by Robert Munro in 1878 at Lochlee in Ayrshire (Munro, 1879). He went on to excavate two more, in Ayrshire, Buston and Lochspouts, and these three sites eventually provided the detail for his crannog type-site. Munro published these excavations together with all known accounts of Scottish crannogs in **Ancient Scottish Lake Dwellings** in 1882. His observations and interpretations of the construction, chronology and distribution have not been challenged since (see Cunliffe, 1978, 216, and below). Munro´s work was concentrated in South-West Scotland although he did record observations of crannogs in the Highlands. This latter area was investigated by the Rev. Odo Blundell who actually made underwater inspections of his sites using the cumbersome diving apparatus of the time (Blundell, 1909).

Very few excavations to modern standards have been carried out on Scottish crannogs. The most recent was that of Milton Loch 1 (Piggott, 1953) which did little to resolve questions of construction and tended to confirm Munro´s theories on chronology and distribution (see below). The problems of chronology, distribution and function were tackled by two surveys carried out in the 1970´s, one in Loch Awe (Morrison, 1973) and one in Loch Tay (Dixon, 1982). These have led to the most recent re-evaluation of Scottish crannogs in which the enormous gaps in our knowledge are laid painfully bare (Morrison, 1985).

Ireland

Early interest in crannogs here was aroused as they were revealed during peat-cutting operations and drainage schemes. The work of the Commission for the Arterial Drainage and Inland Navigation of Ireland uncovered 46 alone (Wylie, 1860, 184). Very few excavations were carried out on Irish crannogs during the 19th century although there was sufficient observation and recording to enable Wood-Martin to publish as a companion volume to Munro´s book, **The Lake Dwellings of Ireland** in 1886.

In 1840 Sir William Wilde had published a note on the finds at the historic crannog of Lagore, Co. Meath (Wood- Martin, 1886, 23-25). Between 1932 and 1936 Lagore, together with two other crannogs, Ballinderry No.1 and No.2, were the subject of excavations by the Harvard Expedition (Hencken, 1936, 1942, 1951). The finds from these sites have provided much of the dating framework for the Irish Early Christian period. A number of smaller excavations since then has resulted in a tentative classification of crannogs according to construction technique (Davies, 1942) while a dendrochronological survey of Northern Irish crannogs in the 1970´s has established a sound chronological framework for Irish crannogs (Baillie, 1979).

3.3 Chronology

Scotland

Until recently the only means of dating crannogs lay in the artifacts found on them. The finds assemblages from 23 excavated sites have been summarized by Oakley (1973, Table III) and illustrates the great diversity of objects found. These range from polished stone axes to Romano-British pins and fibulae; from Samian ware to glazed Medieval pottery. In examining this corpus it has to be remembered that, in most cases, only the top layers were excavated and, even where excavation penetrated deeper, very few reached the loch bed. Therefore, the finds may only indicate the latest ephemeral phase of occupation or even a ´frequentus populi´. Furthermore, the significance of artifacts found in the body of the crannog depends on the theory of crannog construction to which one subscribes (see below). If the substructure was built of material derived from earlier structures or middens artefacts from that earlier period are clearly ´derivative´ in the crannog mound and have no chronological relationship to the construction date of the crannog other than as a terminus post quem.

Munro thought that the assemblages from the three sites that he had investigated most thoroughly ie., Buston, Lochlee and Lochspouts, indicated that those sites had been constructed by the Celtic inhabitants as a defensive measure when the Romans withdrew, leaving them to contend with the Angles, Picts and Scots, in other words, during the 2nd and 3rd centuries AD (Munro, 1882, 283). Whilst the standard of excavation and recording on these sites meant that the finds could not be clearly and unambiguously associated with their occupation the finds from the relatively modern excavation of Milton Loch 1 seemed to be securely related to context (Piggott, 1953). The most diagnostic find, a bronze enamelled loop, of a type made in Pannonia in the first two centuries AD, was found lying on the timber floor and thus tended to reinforce Munro´s theories of crannog construction in the immediately post-Roman era. Some 20 years later the wooden ard found below the floor of the Milton Loch crannog was radiocarbon-dated and produced a date of 400bc ± 100 (K-1394). A pile from the site produced a similar date of 490bc ± 100 (K-2027) thus pushing the construction of the crannog back to the first half of the 1st millenium BC. The excavator was forced to conclude that the bronze loop may have been dropped by a ´Roman or native... doing a spot of fishing..´ long after the site was abandoned (Guido, 1974).

During the Loch Awe and Loch Tay surveys samples were taken for radiocarbon dating. The results are listed below;

Oakbank, Loch Tay	595bc ± 55	(GU-1323)	Dixon, 1981
Fearnan Hotel, Loch Tay	525bc ± 55	(GU-1322)	" "
Firbush Point, Loch Tay	190bc ± 55	(GU-1324)	" "
Ederline, Loch Awe	270bc ± 45	(GU-2415)	Morrison,1981

The dated samples, other than those from Oakbank, are from unexcavated sites and, in consequence, the construction phases to which they relate are unknown. Oakbank is, as yet, only a partially excavated site and dates may not relate to the initial construction. However, a more coherent picture is beginning to emerge, with occupation at least during the mid 1st millennium BC. In the light of these new dates, the finds assemblages of the 19th century excavations tend to indicate, at the very least, intermittent occupation over the next millennium.

Samples were also taken from the crannogs listed above for dendrochronological analysis. Ring-patterns of suitable length were examined (up to 257 rings) but none of the samples could be dated (Baillie, pers. comm.). This lack of success with dendrochronological samples of 1st millennium BC provenance is general throughout Scotland. In all, a dozen samples have been taken from a variety of archaeological sites of 1st millennium BC date and none, as yet, have been dated.

Historical sources show that crannogs were occupied and used during the

Medieval Period and continued in use until the late 17th century. Among the latest, is a reference, of AD 1688, describing Loch an Eilean, Strathspey as a useful place in which to put goods and children during times of trouble (Munro, 1882, 22). In several instances, crannogs were fortified with stone castles but whether the actual crannog had been newly constructed or whether an old crannog was being refurbished is uncertain. The latest reference to the construction of a crannog dates to AD 1580 and records the construction, by Mackintosh, of a crannog in Loch Lochy, Lochaber, in which he placed a garrison to subdue the local populace (Morrison, 1985). There is evidence, therefore, that crannogs were used in Scotland for over a period of almost three millennia.

Ireland

Lakeside dwellings and artificial islands were first built during the Bronze Age in Ireland but whether these are the true precursors of the far more numerous Early Christian crannog, has recently been called into question (Lynn, 1983). Sites such as Ballinderry 2 (Hencken, 1942) and Site B at Lough Eskragh (Williams, 1978: dated to 1155bc ± 80) are merely consolidations of a marshy shore by pinning down areas of brushwood and do not constitute a crannog. Sites like Crannog A at Lough Eskragh (dated to 740bc ± 45) and Rathtinaun, Lough Gara (Raftery, 1947) are, Lynn feels, true crannogs in that they would have been entirely surrounded by water and were constructed with dumps of brushwood and a circle of piles. However they are clearly not defensive structures and are much smaller and less substantial than the Early Christian crannogs. Lynn feels that these features and the lack of evidence for crannog construction and occupation during the intervening millennia eliminates these early sites as the precursors of the Early Christian crannog (Lynn, 1983).

A wealth of documentary evidence exists, for the construction and occupation of crannogs during the Early Christian period (Wood-Martin, 1886, 145-160). One of the earliest references to crannogs records, that in AD 651 the High-king of Ireland mustered his armies at the site of Lough Gabhar. This crannog is mentioned several times in the Annals and was obviously the seat of the Kings of Deiscert Brega, who occasionally occupied the high-kingship of Ireland. The crannog was destroyed twice, first, in AD 850 and secondly, by the Vikings, in AD 934 after which it disappears from the historical record. This historic site was equated with the crannog of Lagore, Co. Meath and when Hencken excavated the site he found 3 phases which he tried to relate to the initial construction, before 651AD and to the phases of reconstruction after the destruction episodes (Hencken, 1950). Unfortunately many of the upper layers had been destroyed by earlier "excavations" and the links between documentary and archaeological evidence are altogether tenuous and unsatisfactory.

Hencken used the annalistic dates to date the rich artifactual assemblage from Lagore and his report has formed the basis for the typological framework, stylistic and formal, of Early Christian Period artefacts. Subsequent excavations of crannogs have been ´dated´ using the resulting typologies, thereby apparently confirming the chronology. Raftery (1981) has drawn attention to the circularity inherent in this kind of artifact-dating as, indeed have several other writers. However, the use of scientific dating techniques has tended to confirm Hencken´s broad chronology.

Independent evidence for a floruit of crannog-building in the Early Christian period was provided by a dendrochronological study carried out in Belfast in the 1970´s (Baillie, 1979). Looking for material to extend his long oak chronology back beyond the 10th century AD Baillie visited a number of Northern Irish crannogs and sampled whatever timbers were accessible to him. Despite the random nature of the sampling the timbers produced two remarkably tight clusters of dates (op. cit. Table 3). Some six crannogs contained timbers ranging in date from AD 553 ± 9 to AD 622 ± 9, in other words, all had been felled within a 70-year period. This indicates a very active and rapid phase of crannog-building in the late 6th and early 7th centuries AD, possibly in response to the aggrandising activities of the Ui Neill clan in the North of Ireland (Mac Niocaill, 1972).

The other cluster of dates occur in the medieval period where four crannogs produced timbers ranging in date from AD 1476 to 1536. As they produced no material of an earlier date which one might expect from the random sampling of multi-period sites, these results again seem to indicate a bout of crannog-building, again during a period of unrest. Crannogs were certainly heavily defended in this period and during the course of the 16th century there are many reports of attacks by Elizabethan forces on crannog strongholds (Wood-Martin, 1886). An illustration, of approximately AD 1600, shows a heavily stockaded crannog in Lough Roughan, Co. Tyrone, being attacked by Mountjoy´s forces (Norman & St Joseph, 1969). Many crannogs were destroyed during the wars with the English and they seem to have gone out of common usage during the 17th century.

3.4 Construction

Scotland

The "keyhole" nature of the 19th century excavations and the lack of plans and sections makes it extremely difficult to determine exactly how the crannogs had been constructed. A number of features are mentioned frequently and two main types of construction seem to be indicated. The first type, represented by Lochlee (Munro, 1879) consisted of successive layers of logs laid parallel to each other and each set at right-angles to the layer below. At Lochlee these layers were secured by stakes driven through prepared holes in the timbers but at some sites there is no evidence of pinning.

Crannog structures varied considerably in height. A trench at Lochlee was excavated to the loch bed and the log layers were stacked 10 ft above the loch bed, the uppermost layer forming the "log pavement" or occupation surface. The second type is what Davies described as a "Packwerk" crannog (Davies, 1942) , where layers of brushwood, timbers, peat, stones, bracken and midden debris etc. were dumped and then contained and pinned down by piles driven into the lake bed. The crannogs in Dowalton Loch, Buston and Lochspouts appear to be examples of this type.

Given that the crannogs were built in water (the Loch Tay sites lie in 3m to 5m of water) some difficulties must have been encountered by the users of both of the proposed constructional techniques. Munro envisaged the floating of rafts of logs over the chosen spot; stones, brushwood, extra layers of logs etc were then heaped onto it until the whole mass grounded. Piles were inserted and the process was repeated until a sufficient height above the water-line was attained (Munro, 1882, 262). The rectangular grid of oak beams pinned at each junction by trenails, found in Loch Bruiach (Blundell, 1910) could, conceivably, be just such a raft.

The "packwerk" type might also have been constructed in the manner envisaged by Baillie (1982, 257) where, a circle of piles being driven into the loch bed, material was dumped into the enclosed area until sufficient height was attained.

A number of problems with either method are immediately apparent, not least of which is that the bulk of the debris would float away unless securely weighted by stones, which do not occur that frequently within the excavated mounds. At Eaderloch, Ritchie concluded that the basal timbers would have had to be laid on the dry loch bed and suggested that the builders may have cut a sluice to alter the water level for this purpose (Ritchie, 1942). An alternative explanation is provided by new evidence from Oakbank crannog which suggests that some crannogs, especially the "packwerk" type, may have originally been free-standing pile dwellings and the superimposed layers that now make up the body of the crannog are the occupation debris and partially collapsed floors from the settlement above (Dixon, 1985, and below). This theory is supported by the evidence from Loch Kinellan where the wood floor lay under 4 ft of occupation debris (Frazer, 1917).

One of the most obvious features of Highland crannogs is their stoniness, prompting the name "crannog-cairn" (Davies, 1942). Many appear as small stony islands with an established cover of vegetation. This has fostered a belief in a division between Highland stone crannogs and lowland wooden crannogs (Piggott, 1953). In fact excavations such as Loch Kinellan and Oakbank, and the Loch Tay and Loch Awe surveys have demonstrated that most of the highland crannogs also have a large wood component and that the stones are merely a capping. The function of the stone capping is difficult to understand. Deep banks of stones have been observed around the base of some crannogs which may well have formed a breakwater. It is of interest to note that a Scottish monastery granted the lease of a crannog on condition that stones be placed outside the piles each year to protect the structure (quoted in Wood-Martin, 1886,31). Dixon has recently suggested that the stone capping represents a much later phase of refurbishment, taking place after the piles had rotted to the level of the protective organic deposits (Dixon, 1985; and below). However, it is difficult to see this event taking place simultaneously on all highland crannogs.

The one feature that is mentioned in even the most indistinct accounts are the number of piles present. These were found throughout the body of the mound as well as encompassing the crannog either as a single line of piles as at Dumbuck in the River Clyde (Bruce, 1900), or as a swathe some 20yds wide as at Dowalton Loch (Stuart, 1865). Obviously, their function in many cases was to secure and contain the mass of crannog material underwater but their interpretation does raise the question of the superstructure of the crannog. At both Lochlee and Buston two of the outer circles of piles were joined by a series of radially and transversely laid beams morticed into the piles, thus forming a lattice-like framework around the crannog (Munro, 1882, plates II, IV). Munro thought that this framework was designed to give the structure rigidity and at Lochlee, where it appears to be above the level of the log pavement he postulated a raised platform or catwalk around the crannog. Where the piles form a closely spaced circle, as in the outermost circle at Buston, they may have been connected by woven wickerwork, forming an impenetrable stockade. At Milton Loch 1 Piggott postulated a wall of horizontally laid timbers wedged between the innermost circle of piles to form the outer wall of her house (Piggott, 1953). It is probable that many of the piles found in the interior of the crannog performed some function in the superstructure, such as wall posts, roof supports, or partition walls but it is extremely difficult and dangerous to extrapolate a complete house plan from a jumble of uprights alone. The isometric reconstruction of Milton Loch 1 illustrated in Piggott's report is based on just a handful of piles while the catwalk is borrowed from Munro's interpretation of Lochlee (Piggott, 1953, Fig. 5). The reconstruction is almost entirely conjectural and Morrison provides a number of equally valid alternatives (Morrison, 1985,50). Unfortunately, the Milton Loch 1 house has become the classic image of a crannog in the archaeological literature.

Evidence for the actual dwelling-house is scant in the extreme. Many crannogs have extensive "log pavements" which are assumed to have been the occupation surface. These are often rafts of timbers laid two to three layers deep on top of the "packwerk" material and roughly circular in shape as at Milton Loch 1, or are the uppermost layer of the log stack as at Lochlee where the platform was about 39 ft square. However, if the platform at Lochlee was an occupation surface it seems strange that 7'9" of occupation debris containing four superimposed hearths built up above the platform without any attempt at refurbishing the platform itself. At Buston, Munro traced an innermost circle of large, squared posts which he thought might be the supports of a "pagoda-like building" (Munro, 1882,205) while, at Lochan Dughaill, beams pegged to the floor housed setting for uprights which would have formed a circle 32 ft in diameter (Munro, 1893).

Access to the crannog would be vitally important and in numerous instances, causeways of stone and wooden piles are recorded. If, however, the crannog was built as a defensive structure then the causeway also provided a means of access for the enemy. Munro suggested that the causeways often lay below the surface of the water thus providing secret access and that the zig-zag layout noted on some causeways was another feature designed to prevent easy access (Munro, 1882, 166). Causeways are sometimes notably absent. Of the 17 crannogs surveyed in Loch Tay, only one (Oakbank) has a causeway, and in Loch Awe none of the 20 crannogs had causeways (Dixon, 1982: Morrison, 1985).

Some crannogs have features which have been interpreted as jetties or harbours. The best-known example is that at Milton Loch 1 where two curving arms of stone form a small harbour on the loch side of the crannog. Similar features were noted on two crannogs in Loch Awe (Morrison, 1985). Small projections of stone on a number of the Loch Awe crannogs might be jetties but none have so far been excavated.

Ireland

Although Davies notes instances of crannog-cairns and log- platforms similar in appearance to the Scottish examples, the majority of excavated crannogs in Ireland are of the "packwerk" type (Davies, 1942). Dumps of brushwood, interspersed with layers of peat, form the basis for the crannogs of Lagore and Ballinderry. At Ballinderry No. 1 the foundation was a raft of logs which, like Eaderloch, were pinned to the loch bed when the water was sufficiently low (Hencken, 1936). Smaller timbers were arranged radially around the raft and then peat, brushwood and compressed vegetable matter laid on top of this. Hencken states that the layers are irregular across the crannog suggesting dumps of material. Very large amounts of animal bone were used in the build-up of both Ballinderry No. 1 and Lagore. At Lagore the foundation layer was a pile of animal bones and Wilde records that 150 cartloads of bones were removed from the site when a drain was dug through it in 1839 (Wilde, 1840). This, together with the quantities of re-used timbers in the substructure of Ballinderry No.1 and the layers of wheatstraw at Lagore indicates that dump material was being brought from settlements nearby. Hurdle screens were also found laid flat within the crannog body at both Ballinderry No.1 and Lagore and these, again, may have been re-used.

Most Irish crannogs are surrounded by a circle of closely set piles and Lynn (1983) sees this as their chief characteristic. The piles of this circle may well have formed the uprights for the wickerwork stockades so clearly illustrated by Bartlett in c. 1600AD (Norman & St Joseph, 1969). Wood-Martin records that another early worker, Wakeman, found traces of coarse wickerwork around the encircling palisade of the crannog at Lisnacroghera (Wood-Martin, 1886, 33).

At Ballinderry No.1 the pile palisade was later replaced by a palisade built of planks placed edge-to-edge so that the crannog would have looked rather like a barrel from outside. At Lagore a more elaborate palisade of slotted planks replaced two earlier palisades and would have provided an impenetrable wall around the site. Beyond the palisades at Lagore was a fringe of small piles which Hencken interpreted as a lacustrine "chevaux de frise" (Hencken, 1950). A report of an attack by English forces on a crannog in 1566AD described the crannog as being "so bearded with stakes and other sharp wood...", (quoted in Morrison, 1985) suggesting a similar arrangement.

The stratigraphy at Lagore is so jumbled that it is difficult to ascertain whether some of the features that Hencken included in the make-up of the crannog are in fact occupation surfaces and associated dwellings. He traces numerous wickerwork walls still woven around uprights <u>in situ</u>and associated with thin patches of ashes which he interpreted as the temporary accommodation of the crannog builders. At Ballinderry No.1 there is clearer evidence for the dwelling-house. A floor foundation of logs was laid over the ´packwerk´ mound in a horseshoe shape around an original raft which became the location for the central hearth. A hurdle screen lay over the logs and this formed the actual flooring. The wall of this house, preserved only in a small area, was of heavy wickerwork, with withies 5cm thick woven around the uprights, whilst a large central upright post, 30cm in diameter , may have been the roof support. Wickerwork walls and flooring were also found at Loughrea (Wood-Martin, 1886,32).

Although Wood-Martin mentions numerous crannogs where causeways were noted none of the examples excavated so far have had causeways. Similarly, Wood-Martin records a jetty at Drumkeery (Wood-Martin, 1886,298) but, apart from the "quay" structure at Ballinderry No.1 which may be an early medieval addition, none of the excavated examples have clear points of access. As evidence in support of the somewhat controversial replica of a crannog built at Craggaunowen, Co. Clare, Rynne cites two crannogs with pile settings suggestive of a gangway and gate-tower, features incorporated into the crannog replica (Rynne & MacEoin, 1978). Crannog I in Cuilmore Lough, Co. Mayo has a line of stakes set in pairs running towards the former lake edge and Rynne interprets this feature as the remains of a raised gangway. The most interesting feature occurs at Crannog II in Cuilmore Lough where the piles of the two palisades cutting off a marshy promontory increase in size towards the centre of the arc. At this point there is a square setting of four massive posts around which are four large split timbers lying in the same alignment to the palisades. Rynne sees this feature as the supports for a gate-tower and the remains of a pathway running under it (Rynne & MacEoin, 1978, 51).

3.5 Materials

Whilst it is virtually impossible from the available evidence to make any estimate as to the quantities of timber required in the construction of a crannog some information can be gleaned as to species and size of material used. Oak is often the only species mentioned probably because it is so easily identified by its hardness. The method of excavating by spading off deposits militated against the recording of other unidentified "soft woods" (eg. Lochlee; Munro, 1882). In general it would appear that oak was used for all the major structural elements such as the piles, the morticed framework found at Lochlee and Buston, and the log pavements or "floors", although that at Buston was identified as birch. The material is often described as "young oak trees" possibly on account of its size (most structural timbers are described as being between 5"-8" in diameter) but at the Loch of the Clans, the oak is described as "of 30 years probable growth" (Munro, 1882, 34). The brushwood layers and the timbers incorporated into the body of the mound tended to be of non- oak species, predominantly birchwood at Buston and Lochlee with some hazel, alder and willow.

The predominance of oak in the older excavation reports begins to look a little suspicious in the light of the most recent crannog excavations. At Eaderloch, the whole framework of the crannog was constructed of birch and pine (Ritchie, 1942) while at Milton Loch 1, samples from both the flooring and the piles submitted for identification were all alder (Piggott, 1953, 152). This predominance of alder is reflected at the two sites investigated by the author. At Erskine Bridge, the piles were of oak but all the log layers were alder (Crone, forthcoming) whilst the quantities of alder at Oakbank form the subject of this thesis.

In Ireland oak is frequently mentioned in Wood-Martin's descriptions and its predominance is confirmed by Hencken's detailed analyses at Ballinderry Nos 1 and 2 and Lagore. The plank palisades at Ballinderry No.1 and Lagore are almost entirely oak while the pile palisades at both sites are a mixture of oak, ash, alder, hazel and birch. Like the Scottish sites the substructure is a mixture of species. At Lagore hazel predominates but oak,ash, poplar, yew, elm, holly and hawthorn are recorded. The floors tend to be built of fewer species. At Ballinderry No.1 the floor of House 1 was oak and alder and that of House II was built entirely of alder. The wood used in the wickerwork screens was unfortunately unidentified.

3.6 Function

Scotland

Crannogs have, by their very nature, a semi-defensive function but how important the consideration of defence was in their construction and location is not so clear. The provision of a causeway would immediately weaken their defence while the proximity to the shore of some crannogs would place them well within the firing range of missiles etc.

The surveys of Loch Awe and Loch Tay attempted to place the crannog in its landscape so that, by identifying the basic physical constraints on the crannog-builders some insight might be gained into the less tangible criteria for crannog location (Morrison, 1985, 59). It is clear that in both lochs the majority of the crannogs are located closest to those areas of land with the greatest arable potential in terms of soils and slope. That defence was often not the overriding factor in their location is borne out in Loch Awe where a group of natural islands at the head of the loch which would have provided an easily defended position without the effort of construction, have been ignored in preference for isolated locations strung out along the loch shore (Morrison, 1985). Here proximity to cultivable land is clearly all-important.

Since Munro's analysis Scottish crannogs have always been seen as the defended homestead of a farming community and the evidence emerging from the excavation at Oakbank adds detail to this picture. Pollen analysis here testifies to cereal production, the crook-ard found under the floor providing the supporting evidence. The cereal pollen occurs in such high concentrations that it is thought that crop processing was actually taking place on the crannog (Scaife, 1985). The large quantities of sheep droppings found in the organic debris has led the excavator to suggest that part of the crannog at least was used as a sheep pen. The presence of a small range of domestic articles completes the picture.

This may not have been the only function to which crannogs were put. Historical records provide us with a range of alternative possibilities from prison islands, neutral islands where treaties were signed, to feasting islands (Morrison, 1985, 66). Size alone gives some indication that they were used for a variety of purposes. The smallest crannog in Loch Tay, at Milton Boathouse is only 10m in diameter and so close to the shore that it can be reached by wading (Dixon, 1985). Neither its size nor its position suggest a defended homestead. In the same loch, the largest crannog, Priory Island, is some 800 sq.m in area and it still supports the ruins of a large masonry structure of probable Medieval date. Again, it seems unlikely that this crannog was merely a defended homestead.

Ireland

In comparison with the Scottish crannogs the Irish crannogs appear to have been built with defence very much in mind. The stout palisades, the fringe of piles surrounding them and the frequent absence of any means of access all suggest a strongly defensive nature. The historic references to Irish crannogs show that, throughout their long usage, they have always played a defensive role, although this might be more a reflection of the kinds of incidents that were recorded than of the real nature of the crannogs. For a long time crannogs were thought of as fastnesses, or temporary refuges but it is clear from the build-up of midden material at sites like Lagore and Ballinderry No.1 that they were permanent residences where a variety of activities took place. At Lagore, for instance, there is evidence of leatherworking, glass manufacture, bronze-working and the manufacture of bone objects (Hencken 1950). The status of Lagore as a royal residence has already been mentioned. Even if the equation of the historical site of Lough Gabhan with the site at Lagore is not absolutely certain (Raftery 1981), it is clear that some crannogs in the Irish landscape were inhabited by ruling families. That these families ruled over small territories called "tuatha" (see below) rather than large kingdoms, does not detract from the royal status of the sites in question. Indeed it has been argued that the resources required for the construction of a crannog in the first instance, demonstrate that the occupiers of such sites must have been both powerful and wealthy, with access to large reserves of manpower (Lynn 1983).

CHAPTER 4 THE SITES

4.1 Moynagh Lough

4.1.1 Pre-excavation

The crannog at Moynagh Lough lies in a tract of marshy land which once formed the bed of a wide, shallow lake (Bradley, 1983). The lake was drained in the 19th century and now only a small body of water survives, immediately South of the crannog, which was left as a grass-covered mound. Although recognised as a crannog in the last century, it was forgotten until 1977 when it was bulldozed in the course of land reclamation, revealing large quantities of animal bone.The site has been undergoing excavation in a series of short seasons since 1980 and evidence has been revealed of intermittent settlement on the site from the Mesolithic to the Early Christian period.

4.1.2 The Excavation

During the Mesolithic period advantage was taken of two natural knolls of dry land within the lake to throw down small stones, pebbles and brushwood of hazel and brambles into the lake thus forming a small platform (Fig.1). A layer of charcoal flecked mud lay over this platform and 100 pieces of flint and chert were found in and on this layer. There were both implements, flakes and chips of flint and chert indicating that knapping was actually taking place on the knolls (Bradley, 1983). Charcoal from this layer (Bradley, 1984) produced a C14 date of 5270 ± 60bp (GrN-11443).

Following this period the lake water rose covering the Mesolithic levels with a deposit of lake mud which almost reached the highest point of the knolls.

The site was again used in the Early Bronze Age when a scatter of small stones were laid directly on the lake mud (Fig.1). A thin layer of charcoal-flecked mud contained within it two spreads of charcoal, sherds of cordon decorated vessels and a barbed and tanged arrowhead. A C14 date from one of the charcoal spreads produced a date of 3460 ± 35bp (GrN-11442).

After a brief abandonment during which lake mud covered the Early Bronze Age deposits the site was re-utilized during the Later Bronze Age (Bradley, 1984). The occupation deposits consisted of a stone scatter, and patches of burnt bone within a matrix of charcoal-flecked clay (Fig.1). Finds from this level included a bronze leaf-shaped spearhead, a jet bead and amber bead, fragments of jet bracelets, potsherds and a stone ring (Bradley, 1984; 1986). A C14 date from the charcoal flecked clay produced a date of 2650 ±80bp (GrN- 1235; Bradley, 1986).

Finally, in the Early Christian period a crannog was built around the knolls. Excavation has not yet penetrated to any great depth into the body of the crannog but it appears that the greater part of it was built up of redeposited peat with layers of brushwood and gravel, consolidating the lake mud around the knolls and extending West and North into deeper water. In the SW section of the crannog an area of woven brushwood, possibly a hurdle screen but too fragmented to be certain, had been thrown down (Fig.1). Very similar features were recorded at Lagore.

Two palisades have been uncovered, the outermost one, Palisade 2, enclosing an area approximately 40m in diameter (Fig.1). They are most clearly seen along the North edge of the crannog. They are overlain by occupation deposits to the West but in the Easternmost area of the excavation a single line of posts lying along the projected circumference of Palisade 2 was uncovered (Fig.1). Palisade 2 was constructed of roundwood posts, sharpened to a point and driven into the lake mud in a closely set line. Palisade 1 lies just inside Palisade 2 and was constructed of roughly split planks placed side-by-side with the widest face set towards the interior of the crannog (Fig.5). It has only been uncovered in two small areas but the planks appear to have been arranged in groups of three to five with gaps between each group. The relationship between the two palisades is unknown as yet. There is an almost identical arrangement at Ballinderry 1 with a discontinuous plank palisade inside a post palisade and there it was shown that the former was later than the latter (Hencken, 1951). To the West of Palisade 2 is a group of similarly sized stakes. It is not clear from the excavated evidence whether this is a continuation of Palisade 2 and for the purpose of this research shall be referred to as Palisade 3 (Fig.4).

Sloping out beyond Palisade 2 into the lake were layers of habitation debris containing enormous quantities of animal bone, obviously the rubbish dump of the crannog dwellers (Bradley, 1984). In this area further piles had been driven in to consolidate the crannog edge (Stakeline 4) and, in one instance, a group of horizontal timbers had been pegged down apparently for the same purpose (Fig.5).

Facing due North and into the centre of the lake was the entrance to the crannog (Fig.3). A pathway of roughly split planks was laid across two parallel runners set 1m apart (Bradley, 1986). Several planks had mortice holes but only one contained a peg. Plank 1 had several square-cut mortice holes and may well have been re-used. The pathway ran from the interior of the crannog out through a gap in

Palisade 2 with which it would thus appear to be contemporary. Of the 25 planks that were substantial enough for identification, 17 were of oak (Bradley, 1986).

To the West of the entrance a second row of posts (Palisade 2A) lay just inside Palisade 2 (Fig.3). To the W. of the entrance these lay sloping outwards under the weight of a thick layer of organic material, over which a hurdle screen (F350) had been thrown. More organic material covered the hurdle and a group of posts (Stakeline 3) had been driven through this material, penetrating the hurdle below. The explanation for this group of features is not clear except that the level of activity around the entrance may have required extra consolidation of the crannog perimeter.

A similar level of complexity was revealed along the NW segment, known here as Palisade 3 (Fig.4). In this area the posts of the palisade were joined by a few courses of withies loosely woven just above the shaped tip of each post. Their function is not clear unless it was to secure the position of each post in relation to its neighbours. Lying just inside Palisade 3 was a small group of stakes (Stakeline 2). A patch of coarsely woven brushwood (F307), resembling a collapsed hurdle screen, lay over them (Fig.4). Directly in front of the woven brushwood, towards the crannog interior and concentric with the palisade, lay another line of 18 small stakes which may have formed a small screen (Fig.4). Just beyond this line lay yet another group of small stakes (Stakeline 1) which may have formed the sails of a wattle screen.Short rows of posts had been recorded in this area in previous excavations but not sampled.

On the Western edge of the crannog a jumbled mass of horizontal timbers and piles was exposed (Fig.2). The piles were driven into the lake mud and branches, brushwood and trunks with roots attached lay scattered amongst them. The piles lie along a roughly NE/SW axis at a tangent to the perimeter of the crannog and heading towards the nearest point on the opposite shore. The full extent of this area has not yet been revealed but it has been tentatively interpreted as either a causeway or landing stage (Bradley, 1984, 91).

Within the interior the earliest occupation uncovered so far are the metal-working areas situated along the Northern and Western perimeters of the crannog (Fig.1). The three furnaces, 550 clay mould fragments and crucibles found in these areas indicate that Moynagh Lough was an important metalworking site (Bradley, 1984). Small amber chips, gold wire and moulds for personal ornaments suggest that fine jewellery-making was also carried out on the site. As yet the metal working areas appear to be unassociated with the habitation area in the centre of the site. The round house was built after the abandonment of the metalworking areas on a layer of compacted yellow gravelly soil. An area of approximately 11m diameter was enclosed by a ring of closely set postholes some of which contained the charred remnants of their posts. This ring of posts was encircled by a low, discontinuous ridge of yellow gravel. Within the house, radial rows of small posts may have formed internal partition walls and a group of postholes lying slightly offcentre may have formed some sort of central support for the roof. There was a thick layer of habitation debris within the house indicating occupation over a considerable period of time. The three stone-edged hearths near the centre of the house seem to have been in use simultaneously. An area of burning) which covered the arc of postholes in the North-West may have been the result of the fire which destroyed the house.

The area to the East of the house has not been examined thoroughly as yet but spreads of gravel, a cobbled area and at least another four hearths suggest an area of considerable domestic and industrial activity. In this area the surface of the crannogs seem to have been systematically consolidated by laying down articulated parts of animal carcasses and covering them with redeposited peat.

The evidence for metalworking on the site has already been mentioned. Leather offcuts and worked antler and bone fragments testify to the working of both these materials while a hoard of unfinished staves and lathe cores indicate that both coopering and turning were taking place of the crannog. Analysis of the animal bone has shown that, while cattle, pig and sheep were consumed on the site, they were not necessarily reared by the inhabitants and possibly arrived on the site as dressed carcasses (McCormick, 1983).

The dating of the Early Christian occupation of the site has relied heavily on artefact typologies (see Chapt3.3). The diagnostic finds from the uppermost habitation level were of types that could be dated, on stylistic grounds, from the 7th to the 9th centuries AD. However "... while some 7th century and 9th century traits are present, the period in which these objects could have been in contemporaneous use was the 8th century" (Bradley, 1986, 97). Mould fragments from the stratigraphically earlier metal-working areas suggested a late 7th/early 8th century date for these layers and Bradley concluded that the initial foundation of the crannog was somewhat earlier than 700 AD (Bradley 1986, 97). The successful dendrochronological dating of Plank 1 (S. No. 197) from the entrance area has not served to refine the dating of the site any further. The plank, which contained 385 rings, was dated to AD625 but was clearly re-used in its position in the entrance (Bradley, 1988). At best it provides a terminus post quem for the entrance.

4.1.3 Discussion

The overall impression gained from the site is that it was the residence of a wealthy and powerful family who, together with their attendant workers and artisans, formed a relatively self-sufficient community. They were able to import exotic goods such as tin, amber and "E-Ware" pottery, possibly in return for specialised metalwork, the large-scale manufacture of which is certainly indicated by the quantities of crucible and mould fragments (Bradley, 1986). The archaeozoological evidence indicates that the inhabitants were able to command clientship dues in the form of dressed carcasses from their clients, suggesting that they were of noble status (McCormick, 1987). None of this conflicts with the evidence from other Irish crannogs (see Chapt.3). Similarly the structural features at Moynagh Lough can be paralleled at a great many crannog sites with the exception of the round-house for which there are no good parallels in this context.

The excavated evidence has not, as yet, presented any major problems of interpretation. However, the detailed sampling and recording of the entire wood assemblage exposed during the excavation means that, for the first time on an Irish crannog, questions of the chronology of site construction can be addressed. The matrix in which most of the wood has been found, a churned-up mixture of redeposited peat and mud, has meant that the normal mechanisms of site stratigraphy cannot be employed.

Questions of particular interest are;

1. The chronological relationship between the two palisades
2. The chronological relationship of the "landing stage" to the palisades
3. The chronological relationship between the successive stakelines around the Entrance and along Palisade 24.

4. The extent and timespan of repairs, if any, to the palisades

The answers to these questions will provide a more refined chronology for the duration of occupation on the site than that determined by the artefactual dating methods presently employed.

4.2 Oakbank Crannog

4.2.1 Pre-Excavation

The crannog at Oakbank was first identified during the underwater survey of Loch Tay carried out in 1979 (Dixon,1982). It lies off the northern shore of Loch Tay adjacent to the only catchment of gently sloping land on that stretch of the loch shore. A second crannog, Fearnan Hotel crannog, lies 500m to the West and radiocarbon analysis of an exposed timber on that crannog has produced a date of 525 ±55bc (GU-1322), demonstrating its contemporaneity with Oakbank, at least in part (Dixon, 1981).

Oakbank itself lies c. 30m offshore on the slightly sloping sandy loch bed. It first appeared as a mound of boulders, the top of which is 1m below the surface of water at its summer level. The mound itself is 1.5m high nearest the shore and 3m high on its offshore side and is roughly oval, measuring 22m x25m from edge to edge (Fig.6). Unlike the other crannogs in Loch Tay, Oakbank possesses a number of external features which enhanced its archaeological interest and prompted its excavation. Two rows of oak piles are still visible on the loch bed, running from the crannog to the shore on a somewhat random course, which presumably originally supported a causeway to the crannog. On the western edge of the main mound lies a smaller mound of boulders, referred to as the Extension, and c.7m in diameter and 2m below the surface of the water. It is connected to the main mound by a small neck of boulders and is encircled by several rings of piles (Fig.7).

Two exposed oak piles, one from the top of the mound and one inserted in the loch bed between the two mounds were sampled for radiocarbon analysis prior to excavation. The pile from the loch bed produced a date of 460 ± 60bc (GU-1325) and the pile from the top of the mound produced a date of 595 ± 55bc (GU-1323).

4.2.2 The Excavation

Excavation, underwater, began in 1980 and has been carried out over four seasons (Dixon, 1985). So far an L-shaped area of roughly 65 square metres, has been opened up in the NE quadrant of the mound covering the area of the junction of the causeway with the crannog (Fig.6).

The boulders, some up to 0.5m across and weighing up to 50kg, proved, upon removal, to form a cap, only one stone deep, covering the mound. They also formed a band c. 3m wide around the periphery of the crannog. The boulders on the top of the mound lay over a layer of "fist-sized" stones which, it is argued, had been deliberately laid down (Dixon, 1985,) A thin layer of silty sand and small stones, less than 1cm thick, lay under the "fist-sized" stones and immediately below this was the organic debris which formed the bulk of the crannog and lay directly on the loch bed. Around the skirts of the crannog the boulders lay directly onto this organic deposit. An idealised cross-section of the stratigraphic sequence as it occurs in the excavated portion of the mound is presented in Fig.8. This sequence may not necessarily extend over the whole crannog.

The mound of organic debris was 1.5m thick and consisted of recognisable parts of bracken stems and fronds, other ferns, twigs, straw and leaves in a matrix of comminuted vegetable debris (Dixon, 1985, 205). Although the deposit initially appeared homogenous, layers could be peeled from underlying layers, the division between them often marked by seams of insect puparia, seeds or animal excreta. Localised deposits of fibrous material, and of material with the consistency of sawdust accompanied by quantities of wood chips were also noted.

The excellent preservation of the organic remains has already been mentioned, providing evidence of diet and economy. Masses of hazelnut shells and cherry stones have been found, including a small deposit of cherries with flesh still intact. Seeds of blackberry, raspberry, flax and weeds of cultivation have also been recovered. Unfortunately bone only survives as collagen or as calcined fragments which are unidentifiable. A handful of teeth were recovered and these were identified as almost all cattle, with a few sheep/goat and pig. The excreta of sheep/goat has been found in large quantities on the site prompting the excavator to suggest that part of the site was used as an animal-pen (Dixon, 1985).

A pollen core from the mound has been analysed and records the presence of very high values for cereal pollen, up to 50%TP in places. The analyst suggests that such high values could be produced either by crop processing on the site or because the pollen was incorporated in the animal faeces before they came on to the site (Scaife, 1985). This evidence for cereal cultivation is supplemented by the find of a crook-ard of oak in the body of the mound.

Small finds from the site have been mainly of wood. Utensils include a finely made plate of alder, a coarse dish of alder and a bucket stave of apple/pear wood. 12 splinters of pine, all burnt at one end, have been interpreted as tapers. There are also pins of hazel, a little whistle of cherry/dogrose, and a spindlewhorl, peg and paddle of alder. Only two pieces of pottery have been found so far, one with the carbonised remains of food on its inside surface. A group of roughly perforated stones, possibly net or thatch weights, and a number of whetstones complete the inventory.

Removal of the organic debris revealed the timber structures of the crannog. These are illustrated in Fig.11. No timbers survived above the domed surface of the organic debris. Towards the interior of the crannog were a group of horizontal timbers, F17, laid parallel and aligned NW/SE. This group covered an area roughly 4m x 1m and was up to three timbers deep. The upper surfaces of the uppermost layer were partially eroded. None of the timbers were split or dressed in any way. A jumble of piles lay to the North and East of this area, forming a band around the skirts of the crannog. Most of these were no longer upright but leant out from the crannog at angles of up to 45 degrees. The organic debris has only been removed to loch bed in the small trench cut to expose Section YQ and it is clear that some piles are deeply embedded in the loch bed while some only penetrate the organic layer (Fig.9).

The excavator has attempted to interpret the mass of piles around the crannog in terms of the superstructure they may have supported (Fig.11). The area of horizontal timbers, F17, interpreted as the floor, is delineated along its northern edge by a row of small stakes (F7), possibly the uprights of a hurdle screen acting as a partition. Immediately beyond this is an area of large stones and boulders (F23), remarkably free of piles and beyond this again is a group of substantial oak timbers, F16, which Dixon suggests are the fallen remains of the entrance structure. He sees two large piles and a number of smaller piles, F3 and F4, which flank F16, as possible "doorpost" structures. Stretching away on either side of F23 are two parallel lines of piles, F5 to the SE and F6 to the NW. Dixon interprets these as the outer wall of the house and/or inner walkway supports. Concentric with F6 but lying further outside it is another row of piles, F2, which might be the uprights of the stockade. This is mirrored in the SE by F1 but this feature is not so clear and regular. Beyond these are groups of 2 to 5 piles, F8 - F13, roughly radially aligned, which Dixon sees as the radial supports of an outer walkway. F11 and F13 are more substantial and may be linked to the causeway which approaches the crannog at this point.

4.2.3 Discussion

The excavator´s interpretation of the nature of the structure is quite controversial (Dixon, 1985). Such a site would normally be interpreted as a "packwerk" crannog in which the organic debris has been deposited deliberately on the loch bed until the mound so created rose above the surface of the water facilitating construction (see above). Dixon believes that the crannog at Oakbank was, in fact, a free-standing pile- dwelling and that the organic debris built up around and below the platform during its occupation. He sees this occurring in four phases;

Phase 1; a free-standing timber framework is constructed which supports a living platform, roundhouse and walkway. The C14 date of 595 ± 55bc (GU-1323) relates to this phase which lasts, he argues, approximately 50 years before the joints connecting the platform joists to piles begin to rot.

Phase 2; The site is strengthened by the insertion of more piles, many into the mound of occupation debris accumulating under the platform. This phase, he argues, lasts c. 80 years by which time the original piles are very worn.

Phase 3; The site undergoes major reconstruction with the addition of new peripheral piles and new floor. This phase, he argues, lasts only 30 years because there is very little build-up of organic matter over the upper floor timbers.

Phase 4; The site is abandoned and the uprights erode away to the level of the organic debris, a process which, he argues, may have taken up to 150 years, given that pier piles, over 100 years old, are still visible above the water in Loch Tay (Dixon, 1985, 255).

Finally the site is covered with large boulders and stakes are inserted into the top of the mound. The reasons for this are unclear. Two of these stakes were radiocarbon-dated to 455 ± 60bc (GU-1464) and 410 ± 60bc (GU-1463). The Extension may belong to this final phase as a pile "related" to it gave a very similar date of 460 ± 60bc (GU-1325; Dixon, 1982, 130).

In support of his argument Dixon points to the absence of distinct layers of brushwood, peat, earth and stones at Oakbank, features which, on other crannogs, have been interpreted as indicating a "packwerk" construction. His thesis gains further support from the extremely high concentrations of bracken and fern spores found in the basal deposits of the mound. These he sees as originating from the floor covering or bedding material on the platform above the surface of the water. The spores would fall through the interstices of the platform and accumulate on the loch bed (Dixon, 1985, 248).

How did the organic material build up below the platform? Unless it had been weighed down, or had been waterlogged beforehand, possibly by its inclusion in a midden, most of the material would simply have floated away. Dixon (1985, 204) states that the vegetation in the mound appeared so fresh that it cannot have been subjected to bacterial breakdown, in a midden, for example, for any length of time. In other words it cannot have been very waterlogged when deposited. This argument applies equally to the construction of a "packwerk" crannog but is refuted by interpreting the stone content of such crannogs as weighting material to sink the organic debris.

However, at Oakbank, "It is evident that the boulders were not a significant element in the construction technique of the site prior to the deposition of the peripheral band of stones and the overall covering of the mound" (Dixon, 1985, 218). The contention that the boulder cap is later is based on the belief that, as they lay overthe stumps of the piles they therefore could not have been placed there until the piles had rotted away. However, I wish to argue here that the observed facts would as easily fit the "packwerk" model of crannog construction. In this model the piles are driven in first and midden material is dumped in the centre, possibly weighted down by logs and boulders (Fig.10) Stage 1). Thus boulders are distributed throughout the core of the mound and rest in and around the piles. After abandonment the whole structure conflates due to internal degradation and the boulders settle down until they form a continuous cover over the mound (Fig.10, Stage 2) Any organic material deposited over and above the boulders would eventually be washed away leaving the site with its apparent capping of stones which continued to protect the organic remains below it (Fig.10, Stage 3). Similarly, the remaining piles would erode and eventually break off at the point where the boulders rub against them and the boulders would then collapse in over them.

4.2.4 Conclusions

It would seem, therefore, that either the "packwerk" or the pile dwelling model could explain the archaeologically observed evidence at Oakbank. This is clearly a case where dendrochronology might provide the means of settling the argument. In the pile dwelling model all the material in the mound had to originate from the platform above and, consequently, all the timbers in the mound would, at one time, have had a structural function in or on the platform. Thus the horizontal timbers lying near the base of the mound and aligned radially to the crannog (Fig.9) were once the transverse supports of a walkway which rotted and sank while timbers higher up in the mound represent repairs which have subsequently rotted. Similarly, F17 is a patch of flooring, the joints of which had weakened and the floor subsided onto the mound.

It should, therefore, be possible to ascribe the timber features to the phases outlined above and postulate a set of chronological relationships for the former which can be tested dendrochronologically. This has not proved as straightforward an exercise partly because of the vagaries of the sampling process (see Chapt.5) and partly because of the partially-excavated state of the site. However, a scheme is outlined below;

<u>Phase 1</u> The only group that can be ascribed with certainty to this phase is G1, comprising the horizontal timbers lying on the lochbed. F1-16, comprising all the upright piles in the excavated portion of the site should belong to this phase. However, there were almost certainly repairs and replacements in the pile structure, given that the calibrated dates indicate an occupation lasting from c.800BC to 510-450BC (Dixon, 1985, 260). The partial excavation of the site has meant

that, while all the exposed piles were sampled, their stratigraphic relationships have not been revealed and some of the timbers from these features could belong to Phase 2 or Phase 3.

Phase 2 Only one group of timbers, G3, is clearly secondary but, again, it could belong in Phase 2 or Phase 3.

Phase 3 F17, the uppermost floor level, can be confidently ascribed to this phase. Below F17 lay a very extensive layer of horizontal timbers, F24/G5. Dixon suggests that this layer formed a foundation layer for F17 rather than an earlier floor level because there was no observable build-up of midden material between the two and because the upper surfaces of F24/G5 displayed few signs of wear. He suggests, therefore, that F17 and F24/G5 are roughly contemporary.

One of the upright features, F7, a line of stakes lying between F17 and the "doorpost" structure, appears very closely associated with F17 and may also belong to this phase.

Phase 4 There are no timbers from the main body of the crannog which can be ascribed to this phase. However, if the timber which provided the most recent C14 date for the site is clearly related to the Extension then the Extension piles, G6, belong to this phase.

Whilst few of the timber features and groups can be confidently ascribed to specific phases we should expect, in the pile-dwelling model of construction, a clear progression in chronology from the "early" timbers to the "late" upper timbers. This should not be the case in the "packwerk" model of construction in which all the horizontal timbers within the mound should belong to the single initial phase of construction, contemporary with the original pile structure. A progression in the chronology of the piles representing repairs and additions might also be expected in the "packwerk" model and the relationship between the main crannog and the Extension may be no different from that proposed under the pile-dwelling model.

NB. It should be noted here that the C14 dates quoted in Chapters 3 and 4 fall within that section of the calibration curve described as "the 1st millennium BC radiocarbon disaster" (Baillie & Pilcher, 1983). Between 800BC and 400BC the calibration curve is essentially flat so that any C14 date falling within that section cannot be resolved, in terms of calendar years, to a range of less than 400 years. Therefore, while the group of C14 dates for the crannogs indicate the general chronological range, they cannot be used, as in the case of Oakbank crannog, for finer chronological resolution such as length of occupation.

Baillie MGL & Pilcher JR 1983 "Some observations on the high-precision calibration of routine dates" in Ottaway BS (ed) Archaeology, Dendrochronology and the Radiocarbon Calibration Curve Univ. Edinburgh, Dept. Archaeology, Occ. Paper No. 9, 51-63

CHAPTER 5 THE SAMPLING PROCEDURE AND THE DATA

5.1 Moynagh Lough Crannog

5.1.1 Sampling

Sampling was carried out by the author during the 1982, 1984 and 1985 excavation seasons. A 10cm-thick cross-section of every structural timber exposed during excavation was sampled. In all, 186 samples were taken. 8% of this total were timbers which were no longer in situ but appeared to be associated with a particular structure (referred to in Table 1 as "floating"). Samples were also taken from unassociated timbers but only if they were oaks with long ring-sequences. Samples 196 and 242 fall into this category.

During the 1981 season six samples were taken by the Dendrochronology Laboratory of Queen's University, Belfast, in the hope of dating the site. The samples had proved useless for this purpose and were passed on to me (Q.U.B sample numbers are appended in Table 1). The three samples from one of the entrance timbers (see Fig.3) were also sent to the Belfast Laboratory in 1985. These yielded a 385 year sequence ending in AD 593. After sapwood estimates were calculated the felling date was estimated as AD625. In all, 195 samples suitable for dendrochronological analysis were removed from the site and these are listed in Table 1.

5.1.2 Age and Species

The age structure and species composition of the entire data set have been plotted as histograms in Fig.12. The entrance timber, S.No. 197, with its 385 year sequence, has been omitted from the age histogram because of problems of scale. With the exception of S.Nos 196 and 242, both unassociated timbers with reasonably long ring-patterns, all the material is under 80 years of age and 80% of the data-set is under 40 years of age. This assessment also includes those samples designated "plus" in Table 1. The age given for those samples is only a minimum age because, for the reasons given in the Comments column of Table 1, it was impossible to measure their actual age.

The age structure for the two largest contexts, Palisade 2 and the Causeway, are illustrated in Fig.13. Given the qualification that we may be looking at wood from several phases, both contexts mirror the age structure of the total site assemblage. In most contexts there are too few samples of each species to make their individual graphing useful and if the age structure for each species over the entire site is graphed no significant patterns emerge (Fig.14). There is a relatively even spread of age groups represented in each species although most of the older material is oak.

Nine species have been used in the construction of Moynagh Lough, although there is only one example each of poplar and holly, and only two examples from the Pomoideae family (for discussion on this species see Chapt.12). Oak constitutes 50% of the wood assemblage while ash, willow and hazel form 15%, 10.9% and 10.9% respectively. In Fig.15 the species composition is plotted for the two major contexts. Palisade 2 is almost entirely constructed of oak roundwood with the inclusion of a few timbers of ash, alder, hazel and willow. In contrast the Causeway was built using a wide range of species in roughly equal proportions although ash and willow predominate.

Palisade 1 and Stakeline 4, lying just outside the Palisade, are both entirely of oak. Furthermore, they are all D or E conversions, ie, they have been radially split from larger timbers and trimmed (Crone & Barber, 1981). The two unassociated timbers , Nos. 196 and 242, and the entrance timber No. 197, are also radially split planks but the bulk of the sampled wood is unconverted roundwood (see Table 1).

5.1.3 The Hurdles

The hurdle screen and areas of woven wickerwork were treated somewhat differently. Each sail, or vertical member, of the hurdle screen F350 was sampled. The withies, or horizontal members, were sampled along two transects running across the width of the hurdle, one at either end. This may have resulted in some duplicate sampling. The area of wickerwork F307 was sampled in a similar fashion except that samples were taken from four transects running across the area, to test the possibility that two hurdles had been inadvertently sampled. The total samples for the hurdles were;

	Sails	Withies
F307	24	144
F350	13	205

In the laboratory in Sheffield these samples were randomly sub-sampled so that only half this number were eventually examined. The results of the sub-sampling are dealt with in Chapt.13.

5.2 Oakbank Crannog

5.2.1 Sampling

Most of the wood was sampled during the 1981 excavation season by the excavator, Dr Dixon. Every piece of wood that was removed during the course of excavation was sampled. The smaller pieces were removed whole while slices were cut from the larger timbers. The tops of the visible piles were also sampled. Except for those in the trench beside section YQ (Fig.9) the piles have not yet been fully exposed and, therefore, their stratigraphic relationships are unknown. The samples were then stored, either in bags on the lochbed or in tanks and containers on shore.

At the time of excavation no-one was interested in studying the wood and it was stored thus for two years before I began examining it in 1983. Despite rigorous attempts during that time to ensure that the wood was kept waterlogged a small proportion did not survive. The greatest damage was the obliteration of the sample labels by fungae, rendering them illegible. A third of the samples had to be discarded for this reason, leaving 218 samples. In 1984 a further 40 samples were removed from the piles surrounding the Extension (see Chapt 4), completing the samples used in this study. These 258 samples are listed in Table 2.

Dixon has defined 25 structural features on the crannog (Dixon, 1985; and see Chapt. 4). The vagaries of the earlier sampling process have meant that some features are well-represented whilst others are not represented at all. About a third of the samples have not been allocated to features by Dixon and these have been grouped by me on the basis of their position on plan and in the stratigraphy (Fig.11). These groups do not necessarily reflect distinct archaeological features (with the exception of G6) but have been so grouped to facilitate handling and the organisation of the data. They are described below.

G1 Group of horizontal timbers near base of crannog, seen in Section YQ (Fig.9)

G2	Group of piles lying NW of entrance, possibly associated with F6 or F7
G3	Group of piles, possibly secondary
G4	Horizontal timbers mainly on periphery of mound
G5	Horizontal timbers at same level as F24 but peripheral to main floor area. Possibly same as G4
G6	Extension piles

5.2.2 Age and Species

The age structure and species composition of the entire data-set have been plotted as histograms in Fig.16. 21 samples of the 258 listed in Table 2 were unmeasurable; the ring-patterns of the Pomoideae samples were too indistinct while those of the Elm samples were too distorted. Assessment of the age structure of the remaining 237 samples is complicated by a number of features of the Oakbank assemblage. Although all the wood sampled from Oakbank was unconverted roundwood and should, therefore, present a full growth increment, the outer surfaces of much of the wood has been eroded by water movement and abrasion against stones and other timbers. Consequently we cannot be confident of the outermost rings. Furthermore, the outermost rings of alder wood are often compressed around the circumference of the tree (see Chapt. 6 for discussion). The figures in the "Outer Rings" column in Table 2 is the largest observed discrepancy between the 3 measured radii. The age given for these samples takes account of that discrepancy. For these reason also I cannot specify a felling season as is possible at Moynagh Lough (see Table 1).

78.5% of the measured samples are under 40 years of age, a similar proportion to that found at Moynagh Lough Crannog. With the exception of five timbers, all the wood is under 90 years of age.

Eight species were used in the construction of Oakbank Crannog although only three are of any importance. Alder constitutes 62% of the wood assemblage while oak and hazel form 21% and 9% respectively. Ash, birch, willow, elm and members of the Pomoideae family occur in scant amounts.

The age structure of the alder and oak are illustrated in Fig.17. The alder ranges from 8 to 75 years although, again 84% is below 40 years of age. The oak has a much greater age range and every sample on the site over 75 years of age is oak.

As described above many of the contexts at Oakbank are poorly represented. I have, therefore, grouped together all the horizontal timbers, F17, F24, G1, G4 and G5 and all the piles, F1 - F15, F18, F19, F22, G2, G3 and G6 and graphed their collective age structure and species composition (Figs.18 & 19). Some small differences emerge. The piles at Oakbank are predominantly alder, while a greater mixture of species has been used in the flooring. The timbers used for the piles and flooring range widely in age, although, on the whole, slightly older timbers tend to have been used as flooring. Few significant features emerge when the assemblage is assessed according to context. F16, the entrance superstructure, is composed entirely of the older oaks, while G6, the group of Extension piles, is entirely alder, with the exception of two willow samples.

CHAPTER 6 RESEARCH PROBLEM 1; GIVEN THE NATURE OF THE WOOD ASSEMBLAGES UNDER INVESTIGATION, CAN SITE CHRONOLOGIES BE CONSTRUCTED?

6.1 Introduction

As described in Chapter 5 the wood assemblages from Moynagh Lough and Oakbank consist mainly of non-oak species with ring-sequences less than 50 years in length. The techniques and methods used in dendrochronology in this country are well-documented elsewhere (Baillie, 1982; Hillam, 1979) and it is sufficient to say here that, on the whole, they have been applied mainly to samples of oak with sequences of 100 years and more. It is the purpose of this chapter to examine the small body of work concerned with the dendrochronology of non-oak species and short ring-sequences, firstly to assess whether my proposed research is at all viable, and secondly, whether any of the approaches and techniques described in the literature could be usefully applied to the material from Moynagh Lough and Oakbank.

6.2 The dendrochronology of non-oak species

Dendrochronological work in Britain, and on the Continent, has tended to concentrate on oak because it fulfils all the criteria necessary for successful chronology construction. It has a reliable and easily measurable ring pattern, it is long-lived and has been continuously used as a building material since the prehistoric period so that samples for every period over the last 2 millennia are available (Baillie, 1982). The species with which I am concerned here - alder, ash, hazel and, to a lesser extent, willow - have not been used to any great extent in dendrochronology because they fulfil few, if any, of these criteria.

None of these species, with the exception of ash, are particularly long-lived (alder lives for c. 60-80 years although older examples have been found (McVean, 1953); the stems of a hazel bush tend to die after 30-50 years but are replaced by new shoots (Rackham, 1980, 209)) thus precluding the construction of long calendrically-dated chronologies. However, timbers of these species occur in such large numbers on particular sites as to constitute an adequate data-base for relative chronology construction. Because they do not grow to any great size, diffuse-porous species such as alder, hazel and willow, are rarely used as major structural timbers and are generally only found as subsidiary timbers in larger upstanding buildings; as components of wattle-and-daub walls, for example. They are more frequently found as structural elements on wetland sites, and on sites in marginal areas, probably because of their availability in the immediate environs of such sites. They are usually either the predominant species, or second-most important, species after oak and therefore, in principle, should be an important source of information on the construction history of the site.

Reluctance to use these non-oak species to any extent in dendrochronology is related mainly to uncertainties regarding the significance of the ring pattern. With the exception of ash, which, in common with oak, is ring-porous, the other species mentioned above are diffuse-porous and, as a result, have less well-defined ring-boundaries which can hamper ring recognition and accurate measurement (see Plates 1-3). Furthermore it is uncertain as to whether these diffuse-porous species actually lay down a growth increment every year, an essential prerequisite for successful dendrochronology.

There are physiological reasons which suggest that diffuse-porous species are more likely to miss out a growth increment than are ring-porous species. Experiments have shown that in ring-porous species conduction of water bearing nutrients etc, from roots to leaves, is limited to the cells in the outermost annual ring. This occurs because the previous years' cells become progressively blocked with tissues called tyloses and rapidly lose their circulatory function (Huber, 1935). In the diffuse-porous species water is conducted through the cells of a large number of annual rings. This implies that it is vital for the ring-porous species to lay down a new ring every year to facilitate water conduction whilst it is not quite so physiologically essential for the diffuse-porous species, given that there are functioning vessels distributed throughout the older part of the stem. Thus, serious doubts arise about both the reliability of the annual ring production and the significance of ring-width measurements of diffuse-porous species.

6.3 Previous modern dendrochronological studies on non-oak species

6.3.1 Alder

The only published modern dendrochronological study of alder is that by Wolfram Elling, of alders from three separate localities in Germany (Elling, 1966). His aims were twofold; to assess the dendrochronological potential of the alder and to assess the degree of similarity between the ring patterns of alder, ash and oak growing on the same site. To this end, he sampled 20 trees of each species from each of the three woodlands, with similar age distributions, in the range of 60 - 115 years.

Elling's initial problem was that of identifying the occurrence of missing rings and discovering their causes. His technique was simply to cross-match the ring-patterns of two opposing cores from the same tree and observe any irregularities between them. If whole sections of the ring-pattern were absent on both cores then cross-correlation with other trees from the same stand would highlight such irregularities.

He concluded that, in the case of strong, dominant alder trees, missing rings were extremely rare. Annual rings may not have grown during periods of diminished growth, resulting, for example, from traumatic damage to the crown or to the foliage. In these instances up to two rings were found to be missing on some trees - he does not say how many - an event which was followed by a return to normal growth. This irregularity did not occur on every tree in the same stand and, therefore, a complete ring-sequence could be achieved if sufficient samples were counted. Alder trees severely stressed by competition with neighbouring trees displayed very irregular ring-patterns (Elling, 1966, Fig. 5, p.163). Elling showed that the earliest part of the sequence is reliable but, once the tree becomes overshadowed, the growth increment is minimised and, in some instances, ceases although the tree is clearly alive. Elling concluded that the critical limit for reliable growth increments was 0.5mm. Below this limit, missing rings become numerous and further measurement of the ring-pattern becomes futile.

Elling (1966, 164-173) then tackled the problem of cross-correlation between alder ring-patterns using visual comparisons and a number of parametric and non-parametric statistical techniques. He concluded that the visual comparisons alone were not adequate to allow judgement of the correlation between two curves (even when, as in this case, they were known to be contemporary). However, he did observe that, compared to other species, alder ring-patterns contained many more signature years and that these were very useful in correlating ring-patterns. For instance, in a sample of 20 alders from Geisenfeld, 16 signature years, over a 94 year period, occurred on all trees and a further 21 signature years occurred on 90% of the trees (1966, p.170, Fig.8). Whilst there was strong correlation between the signature years the intervening sequences of ring-widths displayed low variability and low correlation.

It was this feature that contributed to the low correlation values obtained when Elling calculated the correlation coefficient r for a group of sequences. The data was filtered first using an exponential function but this resulted in very low values for pairs of sequences that looked visually well-matched. Elling then converted the data to indices using a running mean (he expressed each ring-width as a percentage of the previous year-ring). This is not unlike the approach used in the CROS program where each ring-width is converted to an average of five ring-width values of which it is the central one (Baillie & Pilcher, 1973). The spread of r-values obtained for non-correlated and correlated positions using such indices were sufficiently distinct to suggest that the true position, in two sequences of unknown date, would be selected. However, Elling concluded that, given larger sample sets, the distinction might eventually become blurred.

Elling also applied the agreement percentage method (<u>Gegenlaufigkeitsprozent</u>), a non-parametric method still widely used in Continental dendrochronology (Eckstein, 1972). However, the range of agreement values for correlated and non-correlated positions overlapped to such an extent that Elling concluded that the method could not be reliably applied to alder sequences of unknown date.

6.3.2 Hazel

The only published modern dendrochronological study of hazel seems to be that by Ruth Morgan on mature hazel stools from Bradfield Woods, Suffolk (Morgan, 1983). The aims of her study were dictated by her work on prehistoric coppicing in the Somerset Levels and it was not intended to be an exhaustive examination of the dendrochronological potential of hazel. Nevertheless, it produced some interesting results.

Some 19 stems, with 17 to 28 rings, were sampled from two mature coppiced stools. The sequences were too short for any statistical analysis although Morgan calculated the agreement percentage for each match. She found no evidence of missing rings and the high percentage values obtained for the matches (60% - 80%) corroborated this.

The most interesting result was the discovery that, while all the stems on the same stool had started growing in the same year ie, the year that the stool was last cropped, half of the measured sample had stopped laying down detectable growth rings as much as eleven years before the stool was sampled (see Fig.41, p.46) although continuing to live and produce foliage. This is very similar to Elling's results for stressed alder and, similarly, Morgan noted that the last few growth rings produced before total cessation of growth were extremely narrow, as little as 0.2mm in width. Presumably, these stems are also stressed, growing from the underside of the stool and becoming progressively overshadowed by the vigorous central stems. As all hazel grows as a bushy shrub, whether deliberately coppiced or not, it seems reasonable to assume that most hazel bushes will contain some stressed stems in which growth has ceased.

6.3.3 Ash

As a ring-porous species, the reliability of the ring-pattern of ash has never been questioned and the few modern dendrochronological studies of ash are concerned mainly with its degree of correlation with oak for absolute dating purposes.

When Elling (1966) calculated the mean sensitivity of ash, oak and alder trees from three localities in Germany, he found that that of ash was always lower than the other two species and tended to decrease more dramatically with age (see Figs 11 & 12, pp.174 & 176). He then compared the mean curves of each species for each locality and found that, while oak and alder reacted similarly, ash reacted differently at all localities, consequently producing low correlation values. Unfortunately, he did not comment on the degree of correlation between ash trees from the same locality, although he was able to create a mean master for each site.

Calton and Fletcher's study (1978) was far more limited, involving only five ash and eleven oaks from two woods in Oxfordshire. However, their results exactly parallel those of Elling's, in that ash and oak, even when growing close to one another, show very little correlation in their growth patterns. All workers conclude that the ring-pattern of ash is complacent.

6.4 Previous dendrochronological studies of non-oak species from archaeological contexts

Despite the lack of exhaustive modern studies on the species in question several studies of samples found on archaeological sites have been attempted.

6.4.1 Alder

Alder formed the bulk of the wood in two of the trackways in the Somerset Levels; the Neolithic Baker complex (Morgan, 1980) and the Bronze Age Abbott´s Way (Morgan, 1976, 1980). However, although 68 samples of alder from the first Abbott´s Way excavations were examined, the majority were dismissed as unmeasurable, being either too young or too complacent and only a handful (no figures given) were visually cross-matched. A group of five samples, with between 15-22 rings, were found to match together sufficiently well with several of the other species found in the track as to suggest that the wood used in the track was felled in the same year (Morgan, 1976, Fig.13, p22). A group of longer sequences from the later excavation were joined to form a 65-year master.

Some 15 alder samples from the Baker Platform were measured, yielding ring-patterns with between 25 and 53 rings. When matched these fell into two groups, interpreted as representing two trees.

Although we are told that the visual matches between the alder sequences were good (in contrast to Ellings´ observations above), no statistical correlations were made at the time. Latterly, Morgan has run the longer sequences from the Abbott´s Way track on the CROS program, producing t-values ranging from 2.3 to 4.7 (Morgan, 1987).

The only other published account of a dendrochronological study on fossil alder is that of Huber and Merz (1962) on samples from the Urnfield pile-dwelling at Zug-"Sumpf". Some 62 samples, including some over 150 years of age, were available and a master chronology, covering 187 years, was established. Unfortunately, while the archaeological implications of this chronology are discussed the overall approach and specific techniques by which it was constructed are neither described or discussed.

6.4.2 Hazel

The only site where dendrochronological studies on fossil hazel seem to have been attempted, is the Somerset Levels. The Sweet Track has produced 684 hazel stems although only the sequences over 20 years of age were measured for dendrochronological analysis (Morgan, 1984). Many of these cross-matched extremely well and groups were joined to form mean curves. Morgan calculated percentage values for comparisons between the mean curves and agreement is very high (values of 69% - 81% were produced). More recently t-values for the mean-curve comparisons have been calculated and confirm the high level of agreement, some producing t-values as high as 7.8 and 11.6 (Morgan, 1988).

Similarly high levels of agreement between hazel samples from the same site have been found at Rowlands Track and the Walton Heath track (Morgan, 1977) while, on the Baker Platform, Morgan found that the hazel sequences matched very well with the alder mean curve for that site (Morgan, 1980).

6.4.3 Ash

The largest sample of ash from the Somerset Level trackways came from the Sweet Track where young ash stems were used as pegs and older trunks were split for planks (Morgan, 1984). Morgan was able to visually cross-match 20 ash sequences, ranging from 50-150 years in length, and sampled from along the entire length of the site. A 162 year master chronology was established which cross-matched very well with the oak chronology for that track, giving a t-value of 6.9. A similar result was found at Zug-"Sumpf" where a 283 year ash chronology matched the oak chronology very well (Huber & Merz, 1962). It must be noted that this differs significantly from the results of comparisons between modern oak and ash samples (see above).

Morgan had difficulty matching shorter ash sequences along the length of the site. Whilst small groups of ash pegs of 20-25 years growth were remarkably consistent internally, they would often display little similarity with groups from elsewhere on the site. Morgan interpreted this as evidence of differing woodland origins rather than as evidence of non-contemporaneity, or the unsuitability of ash for dendrochronology.

6.4.4 Summary and Conclusions

There are a number of observations made in the studies described above which are directly relevant to the research proposed here.

As discussed in Section 6.2 the reliability of the diffuse-porous species to lay down an annual ring is doubtful. Elling's study of modern alder has established that the occurrence of missing rings is relatively rare in strong, dominant alders and, furthermore, that annual rings are most likely to be absent when the growth increment falls below 0.5mm. He observed that while visual matches between alder sequences was poor the agreement between signature years was good and facilitated correlation. These attributes would, however, result in low correlation statis tics (the r-value) even for a correctly-placed match, a feature noted by Morgan in her work on fossil alder, despite the fact that she felt the visual matches between the alder sequences were good (Morgan, 1987).

Morgan found no evidence of missing rings in her study of modern hazel but discovered that hazel would cease growth under stress, an observation also made by Elling on modern alder. This clearly has important implications in the interpretation of any results because, in an assemblage of stems which had been felled and used at the same time, a number may appear to have been felled at an earlier date (Morgan, 1983). It may be possible to identify and consequently eliminate such material because both Elling and Morgan note that, prior to cessation of growth, the growth increment decreases dramatically and becomes unmeasurable.

It would appear from these studies that the dendrochronological analyses of alder and hazel at Moynagh Lough and Oakbank might well be fruitful. However, it was felt that, as the results from Germany indicated that the growth behaviour of alder is not always synchronous at different locations, and as it is the predominant non-oak species, particularly at Oakbank, a study of modern alder sampled from a location close to the site should be examined to establish its behavioural idiosyncrasies. A similar study of modern hazel is not proposed, partly because it is not so important a species at either site, but mainly because time would not allow it.

A combination of visual and computer-generated cross-matching is proposed but, as low correlation statistics are expected from the latter I shall look for a means of reducing dependance on them.

The modern studies of ash give little indication about the degree of correlation that we might expect between ash ring-sequences, although the creation of ash master chronologies from archaeological material suggests that strong correlation is possible. Morgan had some success with short ash sequences from the Sweet Track which are similar in length to the material from Moynagh Lough and, as it is an important element of the assemblage at that site I propose to attempt its analysis.

Willow has not, as yet, been examined, in a modern or archaeological context. Some insight into its potential may be gained by examining the small amounts available at both sites.

6.5 Studies using short sequences

There has long been a widely held view in dendrochronology that the dating of short ring sequences, particularly those less than 100 years, is hazardous. This view is based, to a large extent, on statistical arguments (Baillie, 1982, 84; for further discussion see Chapt 8) but ignores the fact that the vast majority of samples available from archaeological sites contain much shorter sequences (Hillam, 1979). In this section I propose to examine those studies using sequences of approximately 50 rings and less in order to assess;

1) the general approaches to the problem
2) the techniques used
3) the success and validity of the results achieved.

There are only five sites throughout Britain and the Continent from which the published account of exercises using such short sequences are available and it is useful to consider these separately.

6.5.1 Alvastra, Sweden (Bartholin, 1983)

200 piles of oak, 20-50 years of age, and with the bark still intact, were available from this Neolithic pile dwelling. Bartholin used no statistical methods and relied entirely on visual matching. He worked "blind" in that he constructed a chronology without recourse to the

archaeological information. This enabled him to "test" his chronology, against the latter. By plotting the dated piles on the archaeological plan a coherent pattern became clear. There had been a progressive, almost yearly enlargement of the pile rows, thereby confirming his relative chronology.

6.5.2 Auvernier-Port, Lake Neuchatel, Switzerland (Orcel & Egger, 1982; Egger, 1983)

This Neolithic pile dwelling produced some 400 oak piles. Only 362 were measurable and of these, 84% had less than 50 rings and 51% of this figure had less than 20 rings. Furthermore, only 17% of the total still retained the bark. In this study full use of the archaeological information was made in the analysis of the ring-patterns. Contemporaneity was assumed for all sequences from the same structure and from structures thought to be contemporary on the basis of archaeological evidence so the starting point for any cross-matching was the alignment of the outermost ring (Orcel & Egger, 1982, 118). Where it was possible to cross-match these groups, thus obtained, a dendrochronological "ensemble" was constructed. The presence of some longer sequences facilitated comparison with reference chronologies and most of the ensembles were apparently successfully dated. One ensemble, 9040, was only 26 years long and could not be dated dendrochronologically but was assigned to a position in the chronology on the basis of the archaeological evidence. Initial cross-matching of the short sequences appears to have been visual although statistical corroboration was used when matching ensembles against the reference chronologies.

6.5.3 **Auvernier-Saunerie, Lake Neuchatel, Switzerland** (Lambert & Orcel, 1977)

On this Neolithic pile dwelling virtually all the piles were less than 30 years in length (no figures were given). The piles were initially grouped according to the chronological relationships assigned them by their position in the archaeological stratigraphy. Cross-matching was, again, based on visual comparisons but the workers used a group of signature years to justify their results. A group of nine signatures occurred over a span of 14 years on many of the sequences. They calculated that there was only a 0.125% probability of that group of signatures occurring a second time over a 500 year timespan. This timespan was that delineated by the C14 dates for the occupation of the site.

6.5.4 **Fiskerton, Lincs, England** (Hillam, 1985b)

This Iron Age causeway produced 109 measurable oak samples, the majority of which had ring patterns of 15-60 years. Cross-matching was based on visual comparisons with the requirement that each sequence was consistent with at least three other sequences and that it did not appear to match in more than one position. A 167 year floating chronology was constructed from 64 samples, indicating regular repairs to the causeway every 17 years or so. As at Alvastra the Fiskerton piles were also analysed without recourse to the archaeological data and the subsequent discovery of regular pairing of replaced piles tended to confirm the chronology.

6.5.5 **Somerset Levels, England** (Morgan 1987)

This is the only site where short sequences of non-oak species have been examined and most of this this work is summarized above. Short oak sequences have been successfully matched with longer sequences on the Sweet Track. On most of the trackways, Morgan has assumed contemporaneity of samples from the same trackway and cross-matching, again based on visual comparison, begins with the assumption that the outermost ring (present in the majority of cases) of all the samples will be aligned.

6.5.6 Summary and Discussion

All these apparently disparate exercises have several features in common. The initial approach to the problem on many of the sites was to assume contemporaneity of the samples on the basis of the archaeological information. However there is an important difference between the contemporaneity that can be demonstrated archaeologically and that which can be demonstrated dendrochronologically. Archaeological contemporaneity is one of usage and/or deposition while dendrochronological contemporaneity is that of growth and simultaneous felling. In other words, the piles sampled from an archaeological structure may all have been used at the same time, at least in the final phase, but this does not necessarily imply that they were all felled at the same time. Similarly, the piles sealed by the same deposit were not necessarily deposited at the same time nor felled at the same time; the deposit merely gives the piles a **terminus ante quem** for their usage. Therefore by assuming contemporaneity on the basis of archaeological information an element of patterning or bias which may not exist is being introduced into the data-set.

More importantly, we are removing one means, however inadequate, of testing the dendrochronological results. By constructing his chronology independantly of the archaeological information at Alvastra Bartholin was able to test his chronology against the latter (Bartholin, 1983). The inadequacy of the test lies in the fact that, while a positive result is conclusive ie, archaeological patterning confirming the chronology as at Alvastra, a negative result is inconclusive, leaving us with a number of alternative hypotheses none of which are testable ie, that the archaeological relationships are wrong or the dendrochronological relationships are wrong, or both.

A more adequate test of the dendrochronological results would be the use of independant statistical analyses but such analyses have not been attempted at any of the sites. Hillam calculated the t-values for the matches that she had already located visually but this was for descriptive rather than analytic purposes (Hillam, in press). At Auvernier-Saunerie, Lambert and Orcel calculated the probability of a particular group of signature years occurring more than once in a given timespan. Whilst this is not strictly a test of the dendrochronological results, which at this site gave the majority of sequences the same felling date, the very low probability level calculated does lend credence to the chronology (Lambert and Orcel, 1977).

Most of the exercises have resulted in the construction of relative chronologies providing useful information for the archaeologist on phases of construction and repair. Absolute dates for these chronologies were only possible where the short curves could be matched against longer curves from the same site, thus facilitating the creation of a longer site master which could confidently be matched against a reference chronology, as at Fiskerton and Auvernier-Port. In fact, at Fiskerton, the chronological relationships between several of the blocks of short sequences would have remained unknown had it not been for the presence of longer connecting sequences (Hillam, 1985b,

Fig. 6 and see Chapt 9).

6.5.7 Conclusions

The results from the short-sequence studies described above suggest that, while we might expect to be able to construct short relative chronologies with the material available a number of changes in approach and hypothesis-testing are required. These proposed changes therefore constitute our research aims.

Firstly, the assemblage will not be divided according to archaeological context or phase but will be analysed as a whole. The visual cross-matching of such large numbers of sequences (195 samples at Moynagh Lough and 258 samplesat Oakbank) is clearly unmanageable so I propose to design a computer program which will handle the initial cross-matching of the sequences. Such a program, based on statistical comparisons of the data will have the additional benefit of providing an independant means of testing the dendrochronological data. This program will need to be tested itself on data for which the results are already conclusively proved. If it is successful then the dendrochronological results it generates can be tested against the archaeological information within the framework of a much tighter hypothesis. If a positive answer is achieved ie, archaeology corroborates dendrochronology, the result is conclusive; if a negative answer is achieved ie, archaeology does not corroborate dendrochronology, the result is still as conclusive but we can now, with some confidence, pinpoint the archaeological information as being in error.

CHAPTER 7 RESEARCH PROBLEM 2; GIVEN THE NATURE OF THE WOOD ASSEMBLAGES UNDER INVESTIGATION CAN EVIDENCE OF WOODLAND MANAGEMENT BE DETECTED?

7.1 Introduction

The model of man hacking his way through virgin forest to provide for his requirements heedless of its conservation is inconsistent with the evidence from Early Christian Ireland (see Chapt. 2). This portrays a populous but ordered country, divided politically into tuaths, small units which were economically self-sufficient. The wood requirements of the populace would have to be found within the bounds of the tuath and this factor, together with the pressure of a large population, suggests that active conservation of woodland resources may well have been practiced. Furthermore, the early documentary sources hint at some form of woodland management.

The case for some form of woodland management during the 1st millennium BC in Highland Scotland is much weaker. The population was dispersed and it is likely that each settlement would have found sufficient for its requirements in the surrounding virgin forests. Nevertheless, along the lochs accessible woodland would have been scarce, its native habitat further reduced by the cultivation of the narrow strip of flattish land surrounding each highland loch (Morrison, 1985). Small areas of accessible woodland may have been managed to provide for the daily requirements of the numerous crannogs located in the shallow water along the loch shores (Morrison, 1986).

In this chapter a definition of woodland management is offered and previous studies into prehistoric woodland management are examined, in an attempt to provide a model for the examination of the wood assemblages from Moynagh Lough and Oakbank.

7.2 A Definition of Woodland Management

I propose the following definition; woodland management is an optimization strategy aimed at providing the community with a regular supply of wood without jeopardizing the natural regenerative abilities of the woodland. There are a wide variety of ways of managing woodland (Trump, 1928) but one system, known as "coppice-with-standards", has dominated woodland history in the British Isles since, at least the early Medieval period. It is first described in detail at that date but comments in Anglo-Saxon charters and the Domesday Book suggest a greater antiquity. As well as its great antiquity this system has the added advantage, when considered as a model for the examination of fossil wood assemblages, in that it is characterized by a suite of physical attributes which would facilitate its detection in the archaeological record (these are described later).

Coppicing exploits the ability, inherent in virtually all native British deciduous trees, to produce vigorous new shoots from the stump which remains after a grown tree is felled. These shoots will grow whether the tree was felled deliberately to produce them as part of a formal management system, or felled in the course of clearing woodland. The term "adventitious coppice" is used here to describe coppice which results from the simple felling of trees with no management system in mind, while "formal coppice" describes the product of deliberately managed woodland.

This ability is not limited to a single occurrence; if coppiced shoots are cropped a new growth of shoots will appear the following year, and so on. This propensity was incorporated into a formal system of woodland management first described in the 13th century but which has continued, with very little change, to the present day (Rackham, 1980).

The main feature of the system was the regular cyclical cropping of the coppiced understorey. The interval of time between each cropping ie, the coppice cycle, was usually determined by the species being coppiced and the ultimate function of the stems. During the Medieval period the bulk of the products of coppiced woodland was employed in the construction of hurdles for use as fencing or as wattle panels used in wattle-and-daub buildings. A coppice cycle of five to eight years would produce straight, slender stems of the requisite size for these purposes (Rackham, 1980). A small number of trees, known as standards, were allowed to grow to maturity and these provided the more substantial timbers required for house construction. This system, eventually known as "coppice-with-standards", provided wood of every size, satisfying the requirements of the entire community, at a rate of supply consistent with the conservation of the woodland.

A variant of this system is that of wood-pasture and pollarding. In coppiced woodland areas of recently-felled coppice had to be enclosed, either by fences or banks-and -ditches, for up to seven years to protect the new shoots from grazing animals (Rackham, 1980). By pollarding trees the conflicting requirements of pasture for animals and of a renewable source of wood were reconciled. This was, in effect the coppicing of a tree by cutting it at a level some 2-3m above the ground. This facilitated the growth of new shoots above the reach of grazing animals. The crop from pollarded trees would be very much the same as that from coppice cropped at ground level; long straight flexible stems, suitable for a multitude of purposes ranging from panel and basket-making to faggots for fuel.

As noted above, coppicing produces a crop with a number of distinctive macroscopic characteristics. The numerous stems are generally long, slender and relatively branch-free. The basal end, or "heel", where the stem is attached to the stool, tends to be thickened and angular. The diagnostic heels remain attached to the stems only if they were felled by chopping at the junction between stool and stem. Experimental work suggests that this is the most effective way to crop a coppiced stool when using a stone axe (Coles & Darrah, 1977). However, in periods when metal tools were available the springy stem could be more easily severed just above the stool to which the heel would then remain attached (Crone, 1987).

The age structure of a coppiced stool should also be distinctive. If the stool is clear-felled regularly (and, again, experimental work has demonstrated that this is the most efficient way to crop a stool) it follows that, in theory at least, the stems from that stool should be predominantly the same age ie, that of the coppice cycle. Furthermore, as coppice woodland was commonly divided into compartments, each of which was clear-felled on rotation, large areas of even-aged stools should occur (Fig.20b)

7.3 <u>Previous studies of woodland management in archaeology</u>

The main study to date, into woodland management in the prehistoric period, is that carried out by Rackham and Morgan on the trackways in the Somerset Levels (Rackham, 1977; Morgan, 1977). The large volume of wood from some of the brushwood tracks and the woven hurdle trackways displayed many of the macroscopic charcteristics described above. Rackham concluded that, on the basis of those characteristics, the hazel used to build Garvins, Rowlands and the Walton heath tracks must have grown in managed woodland (Rackham, 1977, 66). At the same time, Morgan aged and measured the hazel from these sites and found that, amongst the rods or horizontal members of the hurdle frames, there was a concentration in age of between 3-6 years, together with a tight clustering in diameters. This range encompassed both modern and medieval coppice cycle lengths and was taken, in conjunction with Rackham´s evidence, as indicating an origin in managed woodland (Morgan, 1977, 62). The variation in age was explained as a product of "drawing", the practice of selecting out those stems of requisite size and leaving the remainder on the stool to grow (Rackham, 1977).

These initial observations came to form the basis for a very general model for the examination of prehistoric wood assemblages. Incidence and age were plotted as a histogram and age and diameter as scatter diagrams (see Figs.83 & 84). A concentration in age with or without a similar clustering in diameters indicated an origin in managed woodland whilst a wide spread of both age and size indicated the opposite.

On the basis of these criteria the hazel hurdles used in Rowland´s Tracks (Morgan, 1977), the Walton Heath track (Morgan, 1977), East Moors (Morgan, 1980), the Eclipse track (Morgan, 1982) and the Honeybee track (Morgan, 1985) were all constructed using material felled in formally managed coppice. The age of the coppice varied. The hazel in the Honeybee hurdle had almost all been cropped when 2-4 years old; the East Moors hazel displayed peaks at 4-5 years and 8 years; the Eclipse hazel at 6-7 years; and the Rowlands and Walton Heath hazel at 3-6 years. Hazel used in the brushwood trackways at Garvin´s (Morgan, 1977) and Jones´ (Morgan, 1982) was also coppiced, although the birch, which comprised the majority species in both trackways, displayed no concentration in age and size and was thus interpreted as originating in unmodified woodland. Similarly Morgan concluded that there was no obvious evidence for the management of any of the species used in the Baker Platform, with the possible exception of willow (Morgan, 1980). On the basis of the criteria outlined above alder used in two the trackways was also formally coppiced. The alder in the hurdle trackway at Stileway (Morgan, 1985) displayed a peak in age at 3-5 years. The alder brushwood from section TinA of the Tinney´s Ground (Morgan, 1978) trackway displayed a pronounced peak at 7-8 years while at section TinD (Morgan, 1980) of the same trackway the peak in age occurs at 3-5 years, prompting the suggestion that the material for the track was being cropped from areas of coppice of differing ages (Morgan, 1980). Although the age structure of the ash poles used in the Drove site of the Sweet Track displayed no such concentrations in age, Rackham concluded that their fast growth and extreme straightness could only have been caused by growth in managed coppice (Rackham, 1979). He also found that some of the oak poles from the same track displayed similar characteristics.

To summarize, Rackham and Morgan have proposed, on the basis of their general - though not clearly stated - model, that, in the Somerset Levels from the Neolithic period onwards, hazel and alder were formally coppiced on variable cycles of up to eight years duration, and were being cropped by selectively drawing the requisite size of stem. There is some evidence for the coppicing of oak and ash but on much longer cycles.

7.3.1 Other studies

The Somerset Levels work has stimulated a number of similar, albeit much smaller studies all using the same approach. An analysis of the morphology and age structure of the hurdles from an Anglo-Saxon fishing-weir at Colwick, Notts., led Salisbury to conclude that the hazel rods came from coppice cropped on an 8-10 year cycle (Salisbury, 1981). At the Medieval site of Kirk Close, Perth the morphology of the withies used in some of the hurdle screens indicated an origin in coppiced woodland but their age structure did not display any distinct concentration (Crone & Barber, 1987). Gilbertson has interpreted a single alder "heel", on the basis of its similarity to examples from the Somerset Levels, as proof of woodland management in the vicinity of Skipsea Withow Mere, Holderness during the Neolithic period (Gilbertson, 1984).

7.4 Discussion and Conclusions

The studies of woodland management in the Somerset Levels opened up a new and valuable area of enquiry into palaeoenvironmental reconstruction and provided the initial stimulus for the present research. However, there are a number of weaknesses in the operational model constructed by Rackham and Morgan which suggests that their interpretations should be questioned.

The major weakness of the model is that it is not based on observations of a control sample separate and distinct from the sample examined ie, the prehistoric wood assemblages. The original supposition was based on reasonable conjecture about the age structure of a coppice stool, ie that the stems would all be of similar age, but this was never tested. The fact that assemblages for which coppicing had been deduced on morphological grounds also displayed distinct concentrations in age distribution was then interpreted as supporting evidence for the conjecture.

A consequence of this circularity is that the possible existence of alternative sources cannot be examined. The work on woodland management in the Somerset Levels was underpinned by the supposition that long, straight stems, in the quantities utilized in the trackways, could only have been produced in formally managed coppice woodland (Rackham, 1976). It seems unlikely that virgin forest could produce such large quantities of straight, branch-free stems in even-aged stands, unless they grew in a large clearing caused by some large-scale natural catastrophe (Jones, 1945). As there are no native broad-leaved woodlands extant in Britain today which have not been modified to some degree it is not possible to test this supposition (Peterken, 1981).

However, between the virgin forest that existed c. 4000BC, ignoring small-scale Mesolithic clearances (Morrison, 1980), and the formally managed woodland described in Medieval documents (see Chapt. 1) several transitional states must have existed. The practice of felling or ring-barking trees but without grubbing out the stumps was found to be the most expedient means of clearing forest, whether for building materials or for agricultural land, in the early pioneer societies of Canada and America (Coles, 1976). As trees were felled around early settlements the stumps would have coppiced naturally (see above). Domestic animals, brought "infield" to manure the cleared land would have eaten the new shoots and thus prevented regeneration of the stumps nearest the settlement. In this instance it is interesting to note that, during experimental work into land clearance in Denmark, it was observed that cattle avoided browsing the hazel, the most ubiquitous of all understorey species in the virgin forest of these islands and also the most widely coppiced (Steensburg, 1955). A combination of intensive cultivation and the depradation of browsing animals would eventually have killed the stumps nearest the settlement. However, regeneration would have been at its most dynamic in the ecotone between the clearing and the forest, a zone of coppiced stumps and scrub where the daily requirements of firewood and of wood for small domestic needs would have been collected. While a plentiful supply of timber was readily accessible in the nearby forest, exploitation of the coppicing stumps in the ecotone would have been casual and irregular at first; the odd few stools being cut over to meet the intermittent needs of the settlement. Thus a mosaic of stools of differing age would have arisen on the edge of the woodland (Fig.20a, Stage 1).

As in all man/land relationships population pressure is a major force for change. As the population increased and the clearing expanded to provide more agricultural land, the forest edge would have become more remote and less accessible to the settlement. At this stage, some regulation of woodland exploitation may have become necessary (Fig.20a, Stage 2). Further population expansion will have led to the establishment of new settlements in adjacent clearings in the forest (Fig.20a, Stage 3). With continued and expanding settlement competition between the separate settlements for the, by now, limited woodland resource would have increased until each settlement claimed some of the woodland as its own, probably at a later stage, enclosing it (Fig.20a, Stage 4). Enclosure is an important step in the evolution towards a formal system of woodland management and becomes essential when the grazing pressure of domesticates increases to match or outstrip available pasturage. Enclosure protects the growing shoots from grazing animals, thus guaranteeing a crop, and facilitating the organization of a cropping routine.

As yet we have no timescale for the scenario outlined above except that it took place somewhere between say, 4000BC and AD1200. Although described, for the sake of simplicity, as a linear development from a single origin, the change from virgin forest to managed woodland would have been an organic, piecemeal and asynchronous development advancing and retreating in response to local, regional and national pressures.

Whilst population pressure operated at a purely local level there was still room for expansion without the need for major change (Fig20a, Stage 2). However, the large scale expansion of settlement into marginal lands in the later Bronze Age suggests that, by the period 1400 - 1000BC, the pressure of population on the landscape was a widespread, national phenomonen. Large scale, indeed regional organisation of the landscape, such as that evidenced in the Dartmoor reaves (Fleming, 1979) emerged in many areas of Britain at this time. Climatic deterioration around 1000BC caused a contraction of settlement out of the marginal lands and back into the core areas (Burgess, 1974, 166-7, 194-8). The resulting concentration of population may have put increased pressure on all resources. In the SE of Scotland the following period is marked by an increase in enclosure of settlements, typically in palisaded settlements, some of very large dimensions. This appears, for that area, at least, to have been a period of intensive woodland exploitation (Reynolds, 1982, 54-5). In the succeeding Iron Age widespread landscape management is evidenced in the creation of networks of linear earthworks (RCAHMS, 1956) and the proliferation of extensive field systems (Fowler, 1981). Woodland, as an integral part of this developing landscape, is therefore likely to have come under increased pressure in the later Bronze Age and, during the Iron Age, almost certainly began to be taken into some form of ownership and possibly enclosed. It is therefore somewhat surprising to find formal woodland management postulated as early as the Neolithic period in the Somerset Levels.

Formal management of woodland is clearly an important step in the transition from "wildscape" to landscape (Fowler, 1981) hence the concern here to date the transition from casual exploitation of adventitious coppice to management of formal coppice. How then can we differentiate between formal and adventitious coppice in the archaeological record? Such adventitous coppice would be morphologically indistinguishable from formal coppice and , assuming that clear-felling of each stool was the practice, the age structure of each stool would also be the same. The only substantial difference lies in the manner of their exploitation.

I suggested earlier that casual and irregular exploitation of adventitious coppice would lead to a mosaic of stools of differing ages, whilst the regular management of formal coppice would lead to areas of similarly-aged stools (Fig.20b). At this stage we should, perhaps, consider the mechanism whereby the coppiced stems become incorporated into a hurdle screen. On modern analogy the hurdlemaker always works within the coppice, selecting out from the freshly-felled stems, those of requisite size (Edlin, 1973). Working in adventitious coppice the hurdlemaker would have access to stools of differing age and, in theory, the hurdles he builds, would also contain a range of age groups. Some concentration in age will have been caused by previously patchy exploitation (Fig.20b) and this will also be evident in the age structure of the hurdle. In contrast the hurdlemaker working in formal coppice would have access to only one age group and, consequently, his hurdles should be even-aged. In the building of hurdles there is no question of stockpiling and thereby acquiring a mixture of age groups because, once the coppice stems dry out they lose their flexibility (Edlin, 1973).

Whilst the builders of the brushwood trackways may not have been so concerned about regularly-sized stems and would have collected the entire crop of each stool, the same comments on age structure apply. Working in adventitious coppice he would collect bundles containing a range of age groups while bundles collected in formal coppice would be even-aged. Even if areas of formal coppice of varying age were utilized, the bundles from each area are unlikely to have been mixed but dumped directly in a single stretch of the trackway.

We can now formulate, on the basis of the model outlined above, a set of operational hypotheses for the investigation of fossil wood assemblages in terms of woodland management;

1. The presence of macroscopic characteristics together with a single age group will be taken to indicate formal coppice management.
2. The presence of macroscopic characteristics together with a range of age groups displaying some concentration will be taken to indicate the exploitation of adventitious coppice.
3. The presence/absence of macroscopic characteristics together with an age structure displaying a wide range of age groups with no particular concentration will be taken to indicate the exploitation of unmodified woodland.

These operational hypotheses clearly need to be tested on modern data for which the origin is already known. As mentioned above, there is no unmodified woodland left in this country so Operational Hypothesis No. 3 must remain as such. Similarly there are no areas where adventitious coppice is still being casully exploited. Operational Hypothesis No. 1 can be tested by analysing the age structure of a sample of modern coppice. However, to form a balanced view, one would need to sample a wide variety of species of differing age growing in an equally wide range of edaphic and climatic conditions. Unfortunately, the areas where woodland is still actively coppiced are restricted and such a wide range of conditions are unlikely to be found. I propose to make only a start here by examining the age structure of hazel and alder coppice. Hazel has been chosen because it is still the most frequently coppiced species and samples are relatively easy to obtain. Furthermore, it is the species most commonly found in hurdle screens and wattle-and-daub walls on archaeological sites and therefore, any operational hypothesis based on an analysis of its age distribution will have wide applicability. Alder has been chosen mainly because it forms such a large component of the wood assemblage at Oakbank Crannog (see Chapt 5).

CHAPTER 8 METHODOLOGY

8.1 Introduction

There are two features of the wood assemblages from Oakbank and Moynagh Lough crannogs which might prohibit the successful application of traditional dendrochronological procedures. These features have been dealt with at length in Chapter 6 but I shall reiterate them briefly here. Firstly, the bulk of the species represented at both sites are non-oak species and therefore, are relatively untried dendrochronologically. Secondly, most of the ring sequences, with the exception of a handful of oak samples, shorter than 50 years. The validity of using such short tree-ring sequences in dendrochronology has never been fully investigated. In this chapter the methodology used to tackle the problems posed by these features is described.

8.2 Measurement of the ring pattern

The initial problem presented by the non-oak species under investigation, with the exception of the ash samples, is the lack of clarity, of the ring-pattern. In this section the problems encountered during the measurement of the ring-patterns, and their resolution, are described for each species.

The basic procedures are standard for all species. Sections of each sample, 10-20cm thick, were frozen and their surfaces prepared with a Surform plane. Previous experience has shown this to be the most effective way of producing a smooth, clear surface for the measuring the ring patterns of waterlogged wood. After thawing each sample is measured using standard dendrochronological equipment: a computer-compatible Bannister measuring table and binocular microscope at 20x magnification linked to an Apple IIe microcomputer. The resulting growth increment series are then plotted on logarithmic graph paper. Until recently this was done manually but a computer program now available at Sheffield produces comparable graphs (Okasha, 1987).

8.2.1 The Ring-Pattern of Alder and its measurement

Alder is a diffuse-porous species in which the annual ring boundary is not clearly defined by large early-wood pores, as in species like oak, ash and elm. Instead it is defined by a thin line of compressed parenchyma cells laid down at the end of the growing season. This varies in its thickness around the circumference of the stem. Plate la, a transverse section of alder, illustrates clearly the indistinct nature of the ring boundary. The difficulty in distinguishing ring boundaries was further compounded by the radial, and to some extent, tangential splitting of the samples during thawing. Alder, as a diffuse-porous species, retains significantly more water than the ring-porous species. Consequently, as the water drains away during thawing the cell walls collapse quite dramatically and the fibres are pulled apart, causing the splitting (Plate lb). This made the measurement of growth increments along a continuous radius from pith to bark very difficult. Measurement of the alder ring pattern was attempted using a higher magnification (30x) but it was found that it was easier to distinguish the ring boundary when visible over the larger field of vision available at a lower magnification (20x). If the ring boundary was not immediately visible under the cross-hair it could usually be traced to either side of it. As with many other species it was relatively easy to measure the wide, fast-grown rings but sometimes difficult to discern ring boundaries within a group of narrow rings. Strong, oblique lighting helped, to a certain extent, by highlighting the boundaries by throwing them into slight relief. The splitting described above sometimes hindered this approach.

Discrepancies in the ring pattern

The lack of published reports on the growth behaviour of alder (see Chapt 6) and the difficulty encountered in measuring its narrow rings, undermined confidence in the verisimilitude of the perceived ring-patterns. To improve this, growth increments along three separate radii, ideally at roughly 120 degree intervals around the stem were measured on each sample. Occasionally, with particularly difficult samples, four radii were measured. By visually comparing the growth increment series from these radii discrepancies or abnormalities in the growth pattern could be detected.

False year-ring boundaries

Elling described a phenomenon common in alder which creates false year-ring boundaries (Elling, 1966). The tree is frequently infested by the sapfly (genus *Dizygomyza*) which lays its larvae in galleries behind the cambium. The reduced efficiency of the cambium in the region of the gallery results in a build-up of layers of flat fibrous cells. Thus, a lenticular patch of narrow cells similar to the narrow parenchyma cells laid down at the year-end is formed (Plate 2a). Elling states that these patches, or "Markflecke", occur in almost every alder tree and they certainly occurred regularly in the alder examined in this study.

The "Markflecke" were almost always identified during the actual counting because their boundaries fell within the larger field of vision available at the lower magnification used in this study. If they were not located during counting they were detected during the comparison of the ring-patterns of the measured radii. The "Markflecke" would, however, cause problems when measuring single core samples and, for this reason, core-sampling is not recommended.

Missing or "Missed" rings

In 15 samples a partially missing ring, present on two radii but absent on the third radius, was detected. This seemed inherently improbable and, in all cases, re-measurement located the "missed" ring. Plate 2b illustrates just how faint and indistinct the ring boundaries are in places.

Bad visual matches

Only three samples out of the total of 169 alder samples from both sites proved unmeasurable. However, in seven samples, the three radial sequences could not be visually matched together at all. Among the possible reasons for this are 1) inaccurate measurement; 2) multiple partially-missing rings; 3) extreme distortion of the stem caused by branches, scars etc. These samples were remeasured with no appreciable improvement in the ring-pattern and, consequently, these samples were discarded.

Inner rings

The splitting described above was particularly concentrated at the centre of the samples (Platelb). Consequently it was difficult to locate the pith and, in such cases, measurement had to commence from the first clearly visible ring. Thus, while at least one radius was measured from the pith there is often a difference of up to four rings, and occasionally more, between the beginning of one radial sequence and another on the same stem (Fig.21).

Outer rings

It was observed during the visual cross-matching that, with as many as 22% of the samples, the measured radii did not end at the same year, as one would expect (Fig.21). Occasionally a difference of up to nine years was observed which could usually be explained by damage to the edge of the sample or differential erosion. However, the great majority of the samples retained undamaged sub-bark surfaces and yet still displayed discrepancies of two to five rings. Re-examination of these samples showed that, on those radii with fewer rings, the ring boundaries were very faint just beneath the bark and the rings had become very compressed, to the extent, in some cases, of appearing as one ring (Plate3a). These appear to be cases of suppressed growth , a phenomenon described by Elling (1966; and above). The occurrence of this phenomenon clearly has important implications for the interpretation of any chronology because the outermost year of a sample may not always be the year of felling of that sample. The calculation of a standard deviation similar to that used in oak sapwood estimates is a possible solution but quantification of the problem is difficult. Elling (1966) describes instances where the tree, although living, had ceased laying down annual rings for over 20 years. In these instances cessation of growth was preceded by a gradual diminution in ring-width until the rings are just visible but unmeasurable (Elling, 1966). It should therefore be possible to detect this pattern of suppressed growth and thereby eliminate those samples with potentially large discrepancies. The problem posed by samples with small discrepancies is more difficult to resolve. None of the samples of fossil alder displayed patterns of suppressed growth yet, as described above, many had discrepancies of up to five rings between ring-patterns of different radii. It is assumed here that by measuring three radii, the full complement of growth-rings is recorded. However, the existence of this phenomenon casts doubt, even on those samples with no observed discrepancy, in that the outermost year may not necessarily be the year of felling.

Tree-Masters

Once the discrepancies in the growth increment series from each radius had been resolved, or the sequence discarded, the three radial sequences were averaged together using the CROS program (see below) and a composite tree-master compiled. This would have the effect, as in the construction of a site master, of filtering out the micro-environmental effects on tree growth, thus strengthening the more general climatic signal. These tree-masters (suffixed M) formed the building blocks for the next phase in chronology construction.

8.2.2 The Ring-pattern of Hazel and Willow and their measurement

Many of the comments made about alder in the preceding section apply equally to the other two species under consideration here. Willow and hazel are also diffuse-porous species and were treated in the same manner as the alder. Freezing and thawing had a similarly dramatic effect on the willow samples, causing myriad radial splits over its surface. The hazel samples, on the other hand, retained a fairly unbroken surface after thawing. A low magnification combined with strong oblique lighting facilitated measurement of the ring-pattern of both species and, in all cases, three radii were measured.

Hazel

The ring-pattern of hazel is much more distinct than that of alder or willow. The pores are generally more clustered in the earlywood and form radial clusters in the latewood. These radial clusters tend to end at the ring-boundary thus defining the latter. Only three out of the 43 hazel samples from both sites proved to be unmeasurable.

Very few discrepancies were encountered during the measurement and cross-matching of the hazel ring-patterns. Only one sample had compressed rings at the very end of the sequence which, while visible, were unmeasurable. However, 50% of the hazel from Oakbank had suffered abrasion, perhaps because most of it came from horizontal contexts, and, consequently, analysis of the outermost years was difficult. On those retaining their sub-bark surface five samples had discrepancies in the number of outer years present on each radial sequence. Like alder these amounted to discrepancies of up to five rings. In three cases the preceding year-rings showed a pattern of suppressed growth (Fig.22). None of the hazel from Moynagh Lough displayed any inconsistencies in their outer years.

Willow

Although willow lays down a thin line of compressed parenchyma cells at the end of the growing season in much the same way as alder and hazel, its more dispersed pore pattern makes definition of the ring boundary difficult. For this reason five of the 21 willow samples retrieved from Moynagh Lough were unmeasurable. In two instances as many as four growth rings had converged and appeared as a single ring along a section of the circumference. However, few problems were encountered in the measurement of the remainder. Like alder and hazel difficulties arose mainly in the definition of the outer years of these samples. In three samples the outermost rings were so compressed as to be unmeasurable and in a further three samples discrepancies of one and two years were noted between the outer years of the separate radii.

8.3 Tree-ring Analysis

The standard procedure for crossmatching two growth increment series, or curves as they are more commonly known, once plotted, is well-documented (Morgan; Baillie, 1982; Hillam, 1979 etc) and needs only a brief description here. The graphs of the two curves under examination are compared visually by sliding one over the other until an apparent position of best match is found. This is, however, a very subjective procedure, dependant upon the skill and patience of the dendrochronologist, and the result obtained gives no objective assessment of the "correctness" of that particular position of match.

The CROS computer program was designed in the Belfast Laboratory to do just that (Baillie & Pilcher, 1973). Very simply, the program calculates a t-statistic for each position of overlap between the two sequences being compared. This statistic takes into account the length of overlap at that position and the level of agreement between the two curves, both non-parametric ie. the number of times that the pair of rings for each year respond in the same way, and parametric ie. the difference in magnitude of that response. Therefore, the highest t-value generated during the comparison between two sequences indicates the position of best match. The t-value also purports to measure the probability that the match at that position may have arisen purely by chance. The higher the t-value the lower the probability that it is a purely chance match (but see below). When deriving a probability estimate (p) from t-value tables two figures are required; the t-value and the degrees of freedom, in this case, the length of the overlap, minus one. Baillie (1982) calculated that a t-value of 3.5 would give a significance level of 0.001, ie 1 in 1,000 mismatches, for an overlap of 100 rings. Since then this arbitrary set value of t=3.5 has become the cut-off point for acceptance or non-acceptance of a match regardless of the actual number of degrees of freedom or of the quality of the archaeological hypothesis under examination (which should determine the significance level selected).

The cross-matching of two sequences is, therefore, relatively straightforward; the results of the statistical comparison generally substantiates that of the visual comparison, and there is no conflict. However, the ultimate aim of most dendrochronological work is the creation of a site chronology and its absolute dating against a master series, and this usually involves many more than two sequences. Conflict inevitably arises, usually in the form of; A matches B at x year and B matches C at x year but C does not match A at x year. Because of the haphazard nature of traditional chronology formation, those areas of conflict are rarely located or, if they are, the sequences involved are simply discarded. The haphazard aspect of chronology formation lies in the fact that the only rule regulating the procedure is that applying to the relationship between two sequences ie. accept only good visual matches substantiated by an acceptable t-value. Chronologies are, in fact, built up pairwise (ie, the relationship between A and B is examined, then B and C, A and D etc, etc) and there is no method of examining the relationships between all the sequences involved in a chronology.

Furthermore, recourse to statistical corroboration is not always deemed necessary at every stage in chronology building nor are the t-values for a match selected during visual comparison always checked to see if they are the highest value for that particular comparison. This apparently hit-and-miss approach has never been made more rigorous for the simple reason that, given sufficiently long oak sequences, it is generally successful. Calendar dates are achieved which are acceptable to both archaeologist and dendrochronologist. However, it does mean that only the very best material can be used with confidence and, in consequence, at least 75% of all archaeological material is deemed less than suitable (Hillam, 1979).

8.4 Traditional dendrochronological procedures and short, non-oak sequences

In this section the applicability of traditional dendrochronological procedures to short non-oak sequences is examined.

8.4.1 Non-oak species

The problems that arise when applying traditional dendrochronological procedures to non-oak species are founded in our ignorance of their growth patterning. We simply do not know if they regularly lay down a growth increment annually or whether they occasionally miss a year or even lay down two rings in one year, or whether such omissions or additions are synchronous for a given species in one region or are individually variable. There are physiological reasons, given in Chapter 6, as to why the diffuse-porous species are more likely to miss a ring than are the ring-porous species. However, the few studies so far carried out on the growth-patterns of such species, discussed in Chapter 6, tend to show that this is not the case. Rather than missing a ring and then resuming normal growth, a feature which would cause chaos in cross-correlation, the diffuse-porous species studied, alder and hazel, appear to lay down increments regularly until, if overshadowed or stressed, they simply cease laying down annual increments altogether.

The CROS program, widely used for statistical cross-matching requires that the input data contain no such anomalies as missing rings, and, although the studies described above are limited, they indicate that alder and hazel, at least, are suitable for use on the CROS program. Their unsuitability for submission to traditional cross-matching procedures appears to lie, not in their growth-patterning, but in their age, most of them not living for more than 70-80 years.

8.4.2 The length of the sequence

When cross-matching two sequences the CROS program ignores the first fifteen years of each sequence in its calculation. It is argued that young oaks are fairly insensitive to large-scale climatic signals during the first few years of their lives and therefore, useless for cross-matching (Baillie, 1982). Visual comparison corroborates this by demonstrating that there is insufficient year-to-year variation to allow confident cross-matching even with sequences from the same tree. This applied to all of the species examined in this study and consequently sequences shorter than fifteen years were not used.

However, Baillie (1982) also dismisses sequences of less than 100 years as useless for cross-matching. Insufficient year-to-year variation cannot be the excuse in such cases as witnessed by the early sections of some of Baillie´s own sequences (see, for example, op.cit Fig. 4.1, p.97 and Fig. 5.1, p.120). The arguments against using such short ring-sequences are, in fact, mainly statistical.

It is often forgotten that the t-value is not a statement of fact but a measurement of probability (but see Orton, 1983, Laxton & Litton, 1984 for further discussion). In essence it is an approximation to Bernoulli´s Theorem which states that, if the probability of an event occurring is p(A), and if N independant and identical trials are made, then the probability that the relative frequency of occurrence of A differing from p(A) approaches zero as N becomes very large (Thomas, 1976, 104). Translated into dendrochronological terms, p(A) is the probability of finding the true date, or chronological position, N is the number of overlapping positions, and A is the estimated date, or chronological position, selected during the cross-matching procedure.

Clearly the longer the sequences being cross-matched (and, consequently, the greater the number of overlapping positions), the lower the probability that the match at that position could have arisen by chance. Conversely, the shorter the sequence the greater the probability that the match may have arisen by chance. It is this concept which underlies Baillie's concern about the length of the sequence and is reflected in the low t-values produced by comparisons between short sequences. Table. 4 lists the t-values for comparisons between the two radial sequences measured on each sample of the modern alder. The radial sequences displayed good visual correlation but the t-values indicate low probability despite the fact that the chronological relationships of the sequences are already established. It would seem, therefore, that low t-values in short sequence comparisons do not necessarily indicate incorrect matches. How do we discriminate between the incorrect and correct matches if we cannot rely solely on t-value levels?

Part of the problem manifests itself during the calculation of the r-coefficient, from which the t-value is calculated. The coefficient of correlation, r, measures the goodness-of-fit of the two sequences at each position of overlap. After filtering and transforming the raw ring-width data (for greater detail see Laxton & Litton, 1984) cross-matching of the two sequences, A and B, begins with the positioning of the last term of Sequence B over the sixteenth term of Sequence A. For this and every succeeding position of overlap the data are multiplied together, pairwise (A16 x B1, A17 x B2 etc). The sequence of products are then summed and averaged. This average figure is that used to calculate the correlation coefficient r. If, during the pairwise multiplication, two very large growth increments coincide, their product may dominate the total figure. In a long sequence this effect is reduced because there are more terms but in a short sequence it could produce a t-value suggestive of a match where there is none or a low t-value for an otherwise good match. Thus the sensitivity of the analysis to bias from extreme values is inversely proportional to N.

8.5 Innovation and Modification

In the preceding section the areas where short non-oak sequences and traditional dendrochronological procedures are incompatible were highlighted. These are;

1. Lack of confidence in the ring-pattern of non-oak species
2. Increased possibility of wrongly selected matches in short sequences
3. Haphazard nature of chronology construction
4. Need to increase N and thereby increase probability levels

It is clear that problems 2 to 4 above also affect short sequences of oak and that 3., the absence of a rigorous procedure in the traditional methodology, has implications for all aspects of dendrochronology. Modifications and/or innovations to improve the procedure are now explored.

8.5.1 Modifications

This section deals mainly with problems 1. and 2. above. Problem 1 was tackled by examining a modern sample. It was impossible, within the time limits of this study, to examine a modern sample of every species present on the crannogs so alder was chosen because it is the predominant,non-oak, species on these crannogs and on many other archaeological sites (see Chapt. 6). A sample of living trees, all felled in the same, known year would enable an assessment of the presence of anomalies in the ring-pattern and the suitability of CROS to this particular species. It was decided to continue using this program mainly because it is readily available and is widely used by dendrochronologists throughout Britain.

The version of CROS used in this study is a modified version, although the modifications were not specifically designed to help solve the problems posed in this study. The CROS program has been subject to much criticism, mainly from statisticians who point out that the t-statistic is incorrectly used and has no statistical significance (Steward, 1983, Orton, 1983, Laxton & Litton, 1984). An improvement proposed by researchers in the Dept of Probability and Statistics at Sheffield University (Okasha, 1987), and adopted here, is to replace the t-value with a normalized z-value. During the calculation of the z-value the unfair advantage given to short overlaps by the t-value is removed. Thus, although reducing the overall level of the z-value, it improves the probability that the maximum z-value is selecting out the true position of best fit between short sequences.

It was observed during the measuring and visual cross-matching of alder samples that as many as 36% had a very narrow ring at the beginning of the sequence. As described above the coincidence of these extreme values during statistical cross-matching might result in a maximum z-value for an incorrect match. In the belief that these early rings are a genetically, rather than climatically, determined feature of alder growth, given its frequency throughout the data-set, they were trimmed from the sequences. The problem would, of course, be reduced by the continued use of visual cross-matching as a check on the statistically-generated results.

8.5.2 Innovation

One of the reasons why traditional cross-matching is so haphazard is the daunting scale of comparisons required. For instance, if a site produces 200 timbers, then (200 x 200-1)/2 , or 19,900, visual comparisons would be necessary to check all the possible chronological relationships on that site. The SORT.STRING procedure was formulated by this writer in an attempt to identify groups of internally consistent sequences in large data-sets. Internal consistency is defined thus;

If sequence A matches sequence B at Year X (where X can be derived from some previously established, absolute or relative, master, or from A or B themselves) then sequence C must match both A and B at a position which confirms the relationship between the latter two sequences. If a further sequence D is added to the group it must also match A, B and C in a position which does not bring it into conflict with any of the previously established relationships. In mathematical terms we can state that;
If Sequence A (Na years in length) cross-matches Sequence B (Nb years) at year Yb,a, then Sequence C (Nc years) will be cross-matched, internally consistently if it matches A at Year Yc,a and B at Year Yc,b such that

$$Yc,b = Yc,a - Yb,a + Nb$$

where the first year of Sequence B is numbered 1 and its final year is numbered Nb.

If the chronological relationships between each pair of sequences is defined here as that established by the maximum z-value generated during the statistical cross-matching of that pair, then the sorting of strings of internally consistent sequences can be carried out on the computer (string is used here to describe any group of internally consistent sequences). A variant of the CROS program, CROS_ALL, cross-matches all sequences in a data-set and produced a matrix of the highest z-values generated for every correlated pair together with the position-of-match indicated by that value (Okasha, 1987). I have designed an addition to that program which systematically compares each position-of-match for every sequence in the data-set and then generates strings of internally consistent sequences in descending order of size, the smallest possible obviously being three. This simple program, referred to here as SORT.STRING, provides solutions to several of the problems outlined in 8.5 above. Firstly, by systematically producing manageable groups of sequences whose statistically-based internal relationships are unambiguously specified, the haphazard nature of chronology construction has been eliminated. Even as an initial procedural step in traditional cross-matching this program is of value in speedily sorting out groups whose statistical relationships are known and whose visual relationships can then be readily checked. It would therefore be of value in the dendrochronology of long oak sequences.

However its greatest value lies in the cross-matching of short sequences of any species. In 8.4.2 above, N, in Bernoulli's theorem, was equated with the number of overlaps between two sequences being compared. Clearly, with two short sequences N will be very small and consequently, the probability of an incorrect match occurring is greater. We cannot, therefore, rely solely on a single z-value quote between two short sequences, A and B, to indicate the correct position of match. However, within a string of internally consistent sequences the probability that A is incorrectly placed against B is greatly reduced if C, D, E, F, etc all place A and B in that same relative position even though the individual z-values specifying these relationships are low by traditional standards. In other words, we are increasing N by increasing the number of samples in the data-set and removing our dependance on single z-value quotes. It therefore follows that the larger the string of internally consistent sequences the greater the probability that the chronological relationships thus established are correct.

If a data-set of 150 sequences is submitted for analysis and the largest string produced contains only 15 sequences then the latter is unlikely to form a chronology which is truly representative of the entire data-set or of the context from whence came the data. The sorting procedure needs to be refined further to widen the data-base for chronological construction. To this end three methods were tested;

METHOD 1

The SORT.STRING program produces a vast number of strings many of which, because of the mechanics of the program, are simply sub-sets of the larger strings. However, because of the new combination of sequences within these sub-sets, some will contain a few additional sequences. SORT.STRING.EXT. sorts out these additional sequences by a process of residual analysis;

Step 1; The largest string in the data-set is selected as Target 1.

Step 2; SORT.STRING.EXT. then compares each string with 1 by counting how many sequences in that string are also in Target 1.

Step 3; Those sequences containing a minimum number (see below) of sequences in common with the Target are selected for Step 4.

Step 4; The additional new sequences contained in the strings selected in Step 3 are added to the Target as Extensions.

Step 5; Within a large data-set several large strings may occur which are mutually exclusive ie. none of them contain any sequences in common. The next largest string of this kind would therefore be selected as Target 2 and Steps 2-4 repeated.

The rationale behind this method is the maintenance of as high a degree of internal consistency with the Target string as possible. Table 3 shows a hypothetical data-set and its tabulated Target and Extension. String B contains seven sequences in common with a Target of ten; therefore the probability that the extra sequences brought in with String B, sequences 10 and 12, are incorrectly placed, is very low. On the other hand, String E has only three sequences in common with the Target so the probability that sequence 13, brought in by String E, is incorrectly placed is much higher. By tabulating the results as a matrix the internal relationships of the group as a whole are clearly specified and the diminishing probability for each newly added sequence is apparent although incalculable (N Fiellor, pers. comm.).

METHOD 2

This method is a combination of the SORT.STRING approach and more traditional procedures.

Step 1; The largest string in the data-set is selected and its constituents combined to form a sub-master.

Step 2; The sub-master replaces all its constituents in the data-set which is then re-run on the SORT.STRING program.

The rationale behind this method is that the largest string of internally consistent sequences is also that group with the strongest general signal and, consequently, by combining them we are increasing the chances of selecting the correct chronological relationships in subsequent cross-correlations.

METHOD 3

Method 3 is a combination of METHOD 1 and METHOD 2. Target 1 and its Extension, sorted out in METHOD 1, are combined to form a sub-master. The same procedure as for METHOD 2 is then followed.

The archaeological wood assemblages under consideration in this thesis contain unknown quantities ie,the chronological relationships of the samples and the dendrochronological behaviour of the species. In the next chapter these three methods are tested for effectiveness and reliability on two data-sets for which both these variables are known and on one data-set containing chronologically disparate assemblages.

CHAPTER 9 THE TESTS

9.1 TEST1; THE MODERN ALDER CHRONOLOGY FROM LOCH TAY, PERTHSHIRE

9.1.1 Introduction

The aims of this exercise were twofold;

1. To determine whether alder sequences can be cross-matched
2. To test the effectiveness and reliability of the three methods outlined in the previous chapter.

The alder samples were all taken during September 1984, along a 200m stretch of shoreline directly opposite the crannog at Oakbank in Loch Tay. Fig.23 is a schematic representation of the stand of alders, showing sample numbers and ages of the sampled stems. The alders were rooted in the coarse, sandy beach on the very edge of the loch. They constituted about 70% of the tree species present and, apart from a few willows, were the trees closest to the waterline. Ash, rowan and sycamore also occurred frequently, just above the beach.

Some 30 alder trees were sampled by coring at breast height with a Swedish incremental corer; 14 of them were multi-stemmed, with up to four major stems. Each stem was sampled and its number appended to the sample number of the tree as a whole ie. F16.1, F16.2 etc. Each stem was treated as an individual sample for analysis so that a total of 54 cores were sampled from the 30 trees. Of those, F5.3 was found to be rotten when examined in the laboratory. Cores were extracted along diameter lines so that two radii could be compared to check for discrepancies in the ring pattern (see Chapt. 8). Complete sections of the stem would have been preferable for this task but it was only possible to remove cores from the trees.

9.1.2 Preparation

The cores were mounted and the surfaces pared using a Stanley knife. Fresh alder is very blond in colour, making the ring pattern difficult to discern. Saffranin staining made the ring pattern much clearer and only two samples, F9.2 and F13, eventually proved to be unmeasurable.

The procedures outlined in Chapt. 8 were followed for the modern alder. The two radial sequences were cross-matched visually and then averaged together to form a stem-master. Table 4 lists the t-values for these radial matches. Many are extremely low, possibly reflecting the assymetric growth of the lochside alder (Plate 3b). The outer rings on many sequences were very compressed, to the extent that, in some cases, up to two rings were undetected on one radius (Plate 3a).

After the initial radii matching, a total of 44 stem masters were considered potentially useful for the construction of a modern alder chronology (see Table 4).

9.1.3 Cross-matching

This data-set was not initially subjected to the traditional approach of visual cross-matching on the grounds that this could not have been done objectively as it was known that all the sequences would end in the same year. Instead the 44 sequences were processed using the SORT.STRING program and the results analysed.

Strings containing up to 13 sequences were generated and preliminary analysis was concentrated on those strings containing six or more sequences. The results for each of the methods are given in Table 5.

METHOD 1

By a process of residual analysis 27 sequences, or 61% of the entire data-set, were sorted in their correct chronological positions. All these sequences were contained within strings of seven or more. However, three sequences were also sorted in incorrect chronological positions within strings of seven or more (Fig.24). F4.2 was sorted incorrectly within a string as large as ten sequences. Analysis of the residual strings, all containing six sequences, sorted out a further seven sequences but only one, F24, was in its correct chronological position. Therefore, by examining strings of six or more in this data-set, we would increase the number of correctly placed sequences from 27 (61%) to 28 (63%) but would also increase the number of incorrectly placed sequences from three (6.8%) to 9 (20.5%). According to the law of diminishing returns, a cut-off point at strings of seven-plus sequences would yield the greatest number of correctly placed sequences with the minimum of incorrectly placed sequences. In describing Method 1 I said that the rationale behind this approach was the maintenance of strong internal consistency with the core group but I had not determined the level of that consistency. If we are to apply a cut-off point at seven-plus sequences then it seems logical to exclude all sequences which do not match six or more of the sequences in the Target group in a consistent position.

The results of the SORT.STRING program were checked by visual matching. The majority of the samples display very good visual correlation although a few, for instance, F5.4 and F30.1, would not have been included were they matched on purely visual grounds (Figs. 25 & 31). On the other hand, a number of sequences were thought to match visually well with constituents of the Target group and/or its Extensions but had not been selected out by the SORT.STRING program.

METHOD 2

The 13 sequences constituting Target 1 (Fig.25) were combined to form a sub-master MODALDMA which was then run against the residual data-set on the SORT.STRING program. MODALDMA was not included in any strings greater than six. However, by checking the CROS_ALL results, a further 13 sequences were selected in their correct chronological position, as indicated by the maximum z-value, including two sequences not sorted using Method 1. Using Method 2 59% of the data-set was sorted out in the correct chronological position.

METHOD 3

The seven sequences in Extension 1 were combined with MODALDMA and the resultant sub-master was run against the residual data-set on the SORT.STRING program. No strings larger than five contained the sub-master. Again, by checking the CROS_ALL results a further ten sequences were selected in their correct chronological position as indicated by the maximum z-value. Of these sequences five were additional to those sorted in Method 1. Using Method 3 30 sequences or 68% of the data-set were sorted in their correct chronological position.

9.2 TEST2; THE SHORT OAK CHRONOLOGY FROM FISKERTON, LINCS.

9.2.1 Introduction

The aims of this exercise were threefold;

1. To determine the behaviour of the SORT.STRING program on a data-set of unknown provenance and chronology and to see whether further refinements to the approach were necessary.

2. To compare the results of the SORT.STRING approach in comparison with those achieved using the traditional approach.
3. To determine the success rate of each of the three methods described in Chapter 6.

The Fiskerton assemblage was chosen as a test-case because, although mainly oak and,therefore, dendrochronologically sound, it contained many short sequences and would thus present problems similar to those found in the Oakbank and Moynagh Lough assemblages. Furthermore, a site chronology incorporating many of the short sequences had been constructed using traditional procedures which could be tested using the SORT.STRING approach.

The site of Fiskerton was excavated in 1981 by Naomi Field of the North Lincolnshire Archaeology Unit and revealed two rows of wooden posts, forming a causeway running at right angles to the River Witham. C14 dates for the posts 53 and 553 (2460 ± 70 bp or 510 ± 70 bc [HAR-4472] AND 2280 ± 70 bp or 330 ± 70 bc [HAR-4471]) gave the structure a chronological span of 1010 - 190 BC (Hillam, in press).

The dendrochronological analysis of the material was carried out by J Hillam of Sheffield University using traditional procedures. Out of 142 oak samples 109 were suitable for dendrochronological analysis and, of these, 64 were eventually incorporated into a site chronology.

Apart from a group of nine samples which had been split from much larger trees, the samples were all roundwood, 73 of which were untrimmed and retained their bark. The age range of the roundwood samples was from 14 to 104 years but over half lay between 25 and 50 years, a range similar to that of the alder samples from Oakbank crannog.

The analysis aimed at the construction of a relative site chronology in the first instance, and absolute dating, if possible. Because many of the sequences were so short matches were only accepted if the sequence in question matched well with more than one sequence. A group of four sequences formed the initial core master and sequences were added only if they matched both the master and several of the component sequences of the master. Matching sequences were no longer added when a working master was achieved which was well-balanced (ie, sequences were distributed equally throughout its length) and which spanned the greatest possible chronological timescale. The remaining sequences were compared against the working master and 64 timbers were successfully dated relatively (Fig.26). The construction of this chronology took several months to complete (J Hillam, pers comm) and has now been successfully cross-matched against the Hasholme master (Hillam, 1987) and the EuroBC master (Hillam, pers. comm.) dating the Fiskerton master to 505 - 339BC.

9.2.2 Results

It would have been a more rigorous test of the SORT.STRING program to analyse the entire data-set but shortage of time prevented this and only the sub-set of 64 relatively dated samples were analysed.

The largest string generated by the SORT.STRING program contained 12 sequences. As analysis of the modern alder had demonstrated that errors were kept to a minimum if strings of six or less were discarded, this maxim was also applied to the Fiskerton oak.

METHOD 1

Unlike the modern alder which produced only one Target, residual analysis of the Fiskerton data generated two mutually exclusive

Targets. 26 sequences were sorted out as Target 1 and its Extensions and 18 as Target 2 and its Extensions. Three sequences, 93, 259 and 262, were found in both groups, one of which, 259, was placed in a different chronological position within each group. Furthermore, three sequences in Target 1 and its Extensions, 259, 147, and 94, were consistently placed in a chronological position different to that arrived at by traditional means.

METHOD 2

When a sub-master was formed from the sequences in Target 1 and run on the SORT.STRING program, the sub-master did not occur in any strings larger than six. The sub-master formed from the sequences in Target 2 was run against the residual data-set andappeared in sequences as large as nine. A further 19 sequences were positioned consistently against the sub-master. In all, 29 sequences, or 45% of the data-set, were sorted out in the positions illustrated in Figs.26 and 27.

METHOD 3

The 22 sequences in Target 1 and its Extension 1 were combined to form a sub-master and then run against the residual data-set on the SORT.STRING program. Strings of nine sequences were generated and a further 24 sequences were sorted out correctly in this fashion (in this context the "correct" position is that illustrated in Fig.26, the position arrived at purely by visual cross-matching). Sample 94 was sorted out in its "correct" position although 259 and 147 were incorporated into the master in their "incorrect" positions (Fig.27). Using Method 3 on Target 1 46 sequences, or 71% of the data-set were correlated together.

The 16 sequences in Target 2 and its Extension 1 were treated in the same fashion. This sub-master was included in strings as large as 12 and a further 20 sequences were sorted out. Thus, using Method 3 on Target 2, 36 sequences, or 56% of data-set, were sorted in their correct chronological position.

9.3 TEST 3; MIXING ANCIENT AND MODERN

In the modern alder all the samples were known to be contemporary and, with the Fiskerton data, at least some of the samples were assumed to be contemporary. In this section a data-set containing two chronologically unrelated assemblages was run on the SORT.STRING program to test the extent to which the latter would sort out totally erroneous matches. A proportion of the ancient alder was combined with those modern alder sequences used in the sub-master MODALDMA.

9.3.1 Results

The 20 modern alder samples which form MODALDMA were sorted together with five of the ancient alder samples, X5, X15, X16, X20 and X35. X5 matched eleven of the modern alder sequences in a consistent position and the other ancient alder sequences occurred in strings of seven or more. In other words, had this been a "blind" exercise, these five sequences would have been included in a chronology supported by strong internal consistency.

These matches were checked visually and all have a number of features in common. They all have short overlaps of between 15 and 21 years within which two very narrow rings coincide, producing the maximum z-value, even though there was often very little correlation between the remainder of the overlapping ring-pattern (Fig.28). However, as in the illustrated case of X5, visual agreement was acceptable and, given their occurrence in large internally consistent strings, would certainly have been included in a chronology.

9.4 Discussion

The points for discussion arising from these three test-cases fall into two categories;

1. Those relating to the viability of alder as a dendrochronological species.
2. Those relating to the efficiency and reliability of the SORT.STRING program as an aid in chronological construction.

9.4.1 Alder as a dendrochronological species

Firstly, the illustrated examples in Figs.25, 30 and 31 demonstrate that the alder can display good visual correlation and can therefore be confidently cross-matched on visual grounds alone. Secondly, the success of the SORT.STRING program on the modern alder demonstrates that, although the z-values for the alder correlations are generally low (Table 6) this statistic is as powerful in locating the correct chronological relationships among alder sequences as it is when used on oak (Okasha, 1987).

Some 61% of the modern alder was successfully cross-matched, a result comparable to that achieved with the young oak samples from Fiskerton where 59.6% were visually cross-matched in the traditional way (Hillam, 198). However, some incorrectly positioned sequences are likely to be included in an alder chronology. The modern alder test-case indicates that at least one in ten sequences might be wrongly placed (Fig.28).

During the exercise in constructing a chronology using the modern alder several features were observed which are important in its consideration as a dendrochronological species:

Sensitivity and signature years

Elling, in his studies on German alder, calculated the mean sensitivity of oak, ash and alder and concluded that the ring-pattern of the latter was far more sensitive than those of the other two species (Elling, 1966). Closely related to this feature is the frequent occurrence of signature years in the ring-pattern of alder. Elling observed that the ring-pattern of alder contained many more signature years than oak and that these were extremely useful in cross-matching. These observations are repeated in the Scottish alder.

Three groups of signature years occur in the Scottish alder. During 1965 the ring-width decreases sharply and increases equally sharply in the following year; this signature is found on all the curves covering this period. From 1973 to 1976 there is a "saw-tooth" pattern of decrease, increase, decrease which is found on 26 of the 27 curves covering this period. In 1982 there is a decrease in ring-width and subsequent strong recovery the following year; this signature is found on 18 of the 23 curves covering this period. In the periods between these signature years the ring-pattern does not display the strong year-to-year correlation common in oak. Rather, the sequences display a common overall trend. This explains the relatively low z-values of the alder (Table 6). Unfortunately, while this indicates that the correlation of groups of signature years and overall trend is more useful in alder dendrochronology than year-to-year agreement, it can also cause problems, as was demonstrated during the analysis of the Test 3 data-set. Some 75% of the erroneous matches between the modern and ancient alder were caused by the coincidence of the 1965-1966 signature year in the modern alder with a very narrow signature year in the ancient alder.

Sample length

Fig.29a is a histogram of the age distribution of the Loch Tay alder samples indicating which age groups have been successfully matched. This excludes almost all of the sequences longer than 36 years. A possible explanation is that, as alder ages, the tendency to miss a growth-ring entirely increases, resulting in an aberrant ring pattern. Elling observed this tendency in the German alder (Elling, 1966). There, the phenomenon was accompanied by a gradual diminution in the annual increment until the tree ceased laying down a ring altogether. At another Scottish crannog, Erskine Bridge on the River Clyde, samples of alder, aged on average 90+ years, could only be correlated over their first 60 to 70 years of growth. After that the growth pattern became increasingly erratic (Crone, forthcoming). This pattern of "suppressed" growth is not present at Loch Tay and there is sufficiently good visual correlation between pairs of the longer sequences to suggest that the full complement of rings is present. For instance, in the pair F22 and F26.2 both ring patterns follow a similar trend and , more importantly, there are phases of good year-to-year agreement (Fig.30). Furthermore, some of the longer sequences correlate well with the younger sequences but not with each other eg. F30.1 (Fig.31). This suggests that, at Loch Tay, the problem lies in the earlier part of the sequences and not in the most recent sections, as is the case at Erskine Bridge and in the German alder. The proposition that the longer sequences were more sensitive was examined but, while some of the longer sequences were among the most sensitive, there was no clear relationship between age and sensitivity (Fig.29b).

Outer year-rings

Four of the correlated samples, F1.1, F2, F5.4 and F30.1 display good statistical and visual correlation in their chronological position but all are missing their outermost rings (Figs 27 & 31). Re-examination of the samples failed to detect the rings and it must be concluded that they have either ceased laying down a yearly increment or it has become so small as to be undetectable (see Chapt.8). Whatever the explanation for the phenomenon there appears to be no remedy yet it has grave implications for chronological interpretation. If the chronology illustrated in Fig.31 were that of a fossil assemblage we might well conclude that a few timbers were deposited between 1980 and 1983 prior to a major depositional phase in 1984. In archaeological terms this interpretation is improbable and the presence of such a large proportion of timbers felled in the same year might force the conclusion that the outermost rings of these samples are, indeed, missing. However, in the absence of any major felling phase, this phenomenon would blur fine chronological interpretation.

9.4.2 The SORT.STRING program and chronological construction

The SORT.STRING program has proved to be highly successful in constructing chronologies for both the short oak sequences from Fiskerton and the modern alder sequences from Loch Tay. For Fiskerton the SORT.STRING approach produced a chronology identical to that produced by more traditional means. Method 3 proved to be the most effective method on this data-set, sorting out 71% of the data into a chronology. For the Loch Tay alder, Method 3 also proved to be most effective, eventually sorting out 68% of the data-set into a chronology. One advantage of the SORT.STRING approach was the speed of the analysis. For Fiskerton, analysis of a data-set of 64 samples took days rather than months, while analysis of the 44 modern alder samples was completed within a day. The visual matching of 44 samples and their formation into a chronology can take up to several days using traditional procedures.

As with any methodology, however, there are certain limitations and these became apparent during the analysis of the three test-cases. The Fiskerton test, in particular, has highlighted many of the problems that are bound to arise when analysing any archaeological assemblage which will invariably contain timbers of differing origins and chronological phases.

Master chronology construction

I stated in Chapter 8 that the largest string of internally consistent sequences in a data-set should be an ideal group with which to form a sub-master. However, the evidence from Fiskerton suggests otherwise. When the 12 sequences in Target 1 were combined to form a sub-master which was then run against the residual data-set, the sub-master did not occur in any strings larger than six. The sub-master of Target 2, however, occurred in strings of nine and cross-matched against another 20 sequences including most of the sequences in Target 1. The difference between the two targets is apparent in Figs 26 and 27. Target 1 is comprised mainly of ten short sequences all felled in the same year and, to all appearances, from the same source, while Target 2 is comprised of longer sequences from a number of phases. The lack of cross-correlation with other sequences suggests that the internal consistency of Target 1 is related to strong micro-environmental signals rather than a general climatic signal. By expanding the sub-master to include the Extension sequences, as in Method 3, the local signal is being subdued and the more general climatic signal is being enhanced, hence the greater success in chronology-building using Method 3. This problem is related to the overall coherence of the data-set, discussed below.

Multiple targets and the coherence of the data-set

The size of strings generated by the SORT.STRING program and the number of Targets found within a data-set describe the overall coherence of that data-set.

For example, analysis of the modern alder generated large strings containing up to 13 sequences and yielded only one Target. All strings contained at least two sequences from the original target and there was no second target ie. no alternative large group exclusive of the sequences in Target 1. The process of elimination and residual analysis followed throughout the SORT.STRING package shows that, at each stage, large chunks of the data-set were eliminated and only a small residue left;

Target 1;	86 strings eliminated
Extension 1;	232 " "
Extension 2;	123 " "
Extension 3;	94 " "
Residue;	14

The alder came from a single environmental niche, the loch shore, so that, in general, all the sampled trees were subject to the same macro- and micro-climatic influences. It seems likely that the strong coherence of this data-set is related to its single origin. On the other hand absence of coherence in a data-set of unknown origin may indicate either that the samples are of timbers from several different sources or from several different chronological phases. However, the presence, in the Fiskerton data, of two mutually exclusive targets containing samples of different phases does suggest that the phenomenon of multiple targets is related to the woodland origins of the timbers rather than their lack of contemporaneity. In this instance, it is interesting to note that the nine samples at the base of the chronology in Figs 26 and 27 were not sorted out at all. These are the samples which had been converted from larger trees and clearly came from a different source to the small roundwood samples that constitute the bulk of the Fiskerton assemblage.

The presence of multiple targets will result, in their subsequent analysis, in sequences occurring in more than one target and, as in the case of 259 in the Fiskerton data, occasionally occurring in conflicting positions. The only way, at present, to resolve this conflict is to eliminate such sequences from the chronology. However, it is interesting to note that 259 was incorporated into two sub-masters in differing positions and yet all the additional sequences that matched against each sub-master were placed "correctly". The sequence is clearly in a wrong position in one of the sub-masters but this has not introduced error.

Short overlaps and signature years

The results of Test 3, the mixed data-set, have introduced a cautionary note. Although the combination of short overlaps and the coincidence of two extreme values could theoretically occur when using short sequences of any species it is more likely to occur with alder because of its higher sensitivity and consequently higher proportion of signature years. Because such a combination will often produce a maximum z-value the SORT.STRING program will pick these matches out. The errors cannot be totally eliminated because, as Test 3 demonstrated, some of the erroneous matches were still visually acceptable but, by visually checking all SORT.STRING results and eliminating all matches where the combination of short overlap and two extreme values occur, the error should be substantially reduced.

Recommendations

Analysis of the three test-cases has demonstrated that the SORT.STRING program is an effective and reliable aid in chronology construction. However, certain recommendations are made to improve the methodology and thereby further reduce the chance of error.

1. Method 3 is the most effective method for widening the database from the original Target and Extension.
2. Only strings containing seven or more sequences are to be analysed.
3. All matches should be visually checked and it is recommended that where short overlaps and two extreme values coincide, those sequences be discarded.
4. Any sequence that occurs in more than one position outside the Target and its Extension should be discarded.

CHAPTER 10 THE CONSTRUCTION OF A SITE CHRONOLOGY FOR MOYNAGH LOUGH

10.1 Introduction

Given the success of the SORT.STRING program on two of the sets of test data, this approach was applied to both of the archaeological assemblages. However, both data-sets were also subjected to traditional cross-matching procedures as an additional means of testing the SORT.STRING results. The results are described primarily according to species and, in the traditional approach, according to context. Only maximum z-values are given on the diagram and in the matrices.

10.2 The Traditional Approach

10.2.1 The Oak

Of the 97 samples of oak retrieved during excavation only 81 samples were eventually used; eleven were less than 15 years of age and, in five samples, the radii could not be matched together.

Palisade 1

The five oak samples from this context are all split timbers and, in all cases, the inner and outer rings are missing, either from trimming or damage. Only one sample, 191, retains some of its sapwood. None of the samples from this context matched convincingly with each other.

Palisade 2

13 sequences from this context matched visually well and were combined to form a sub-master SUB-PAL2, 46 years in length (Fig.32) in which all the constituents were felled in the same year. Another six sequences cross-matched with the sub-master (Fig.33). These 20 sequences are all characterized by a gradual increase in ring-width followed by a

sudden decrease in ring-width for a year or two then a subsequent increase, creating a ´signature´ between arbitrary years 34 and 39.

Two pairs, 80/81 and 167/172, were considered to match well whilst 181, 183 and 186, from the Eastern sector of the Palisade, were combined to form a sub-master SUB-PAL2E, 23 years in length (Fig.34). None of these groups match with each other or with SUB-PAL 2.

Palisade 2A

The four oaks from this context matched visually well and were combined to form a sub-master SUB-PAL2A, 29 years long. The chronological relationships thus created indicate that 152, 154 and 155 were felled in the same year and that 159 was felled four years later (Fig.35).

Palisade 3

Most of the samples from this context displayed very erratic growth-patterns, particularly a group of six which displayed a "release" pattern, ie. the ring-width steadily increasing with age. Only four sequences matched visually well and were combined to form a sub-master SUB-PAL3, 22 years in length. Within this sub-master 129, 133 and 142 were all felled in the same year, and 124 was felled one year later (Fig.35).

Causeway

Eight oaks were sampled from this context, of which five were usable. They did not match with each other nor with the oak samples ´floating´ around the Causeway.

Stakeline 3

Three of the four oak samples from this context were usable but they did not match with each other.

Stakeline 4

The outer rings of all three oaks from this context are contorted or missing. Only 193 retains a few rings of its sapwood. 193 and 195 cross-match but, without the sapwood the chronological relationship is ambiguous (Fig.35).

"Floating"

The two unassociated oaks, 196 and 242, both radially split planks, cross-matched very convincingly with a z-value of 12.6, high enough to suggest an origin in the same tree (Fig.36). Unfortunately, lack of association with any contexts together with the absence of sapwood on either sample makes this match of little value.

Intra-context relationships

Palisade 2/Palisade 3

Sub-master SUB-PAL2 did not cross-match convincingly against any other sequence or sub-master. However, some of the individual sequences used in its construction generated matches. 59 and 60 both cross-matched with SUB-PAL3 indicating a felling date in the same year (Fig.37). A match between SUBPAL2E and SUB-PAL3 also indicates the same chronological relationship although 168, another sample from the Eastern stretch of Palisade 2, cross-matched placing SUB-PAL3 two years earlier (Fig.37).

Palisade 2/Palisade 1

59 matches 190 of Palisade 1, both sequences ending in the same year (Fig.37); however, since 190 is incomplete this must indicate that Palisade 2 is earlier than Palisade 1 although we cannot be certain by how much. A match betwen 176, from the Eastern stretch of Palisade 2 and 191 of Palisade 1 also places Palisade 2 earlier than Palisade 1 (Fig.38).

Palisade 2/Palisade 2A

The chronological relationships generated by matches between these two contexts are not at all consistent. 80/81 cross-matches well against SUB-PAL2A, placing the former two years earlier than 159 and one year later than the other constituents of the sub-master, whilst 176 of Palisade 2 matches SUB-PAL2A, making it contemporary with 152, 154 and 155 (Fig.38). SUB-PAL2E cross-matches visually well with SUB-PAL2A placing the former nine years earlier than 159 and six years earlier than 152, 154 and 159 (Fig.38).

Palisade 2/Stakeline 3

151 of Stakeline 3 cross-matches visually well with 53 and 80/81, placing the former one year later than the Palisade 2 sequences (Fig.39). However, 57 from Palisade 2 matches 110 of Stakeline 3, ending three years earlier than the latter (Fig.39).

Causeway

88 of the Causeway cross-matches with SUB-PAL2E suggesting that the former sample was felled one year later than those in SUB-PAL2E. 88 also cross-matches well with SUB-PAL2A suggesting that, in the latter, 159 was felled eight years later and 152, 154 and 155 were felled five years later (Fig.38).

10.2.2 The Ash

Palisade 2

Of the three usable samples from this context 71 and 74 match together well ending in the same year (Fig.40).

Palisade 2A

The two ash samples from this context, 153 and 157, cross-match visually well, again, indicating felling in the same year (Fig.40).

Palisade 3

Three samples of ash were retrieved from this context of which two were usable. These two, 122 and 123, cross-matched visually well indicating felling in the same year (Fig.40).

Causeway

19 samples of ash were retrieved from this context and 18 were usable. 91 and 92 matches so well as to suggest an origin in the same tree. A sub-master CWASH was constructed, combining 91, 92, 99, 100 and 101 (Fig.41). 99 was felled one year earlier than the other samples. One other pair, 90 and 102 match well together, both ending in the same year. 24 and 30 appear to match 106 visually well, a match which places them 26 years earlier than 106 (Fig.42).

Intra-context relationships

The two samples from Palisade 2, 71 and 74, link many of the ash samples together. 74 cross-matches well with the Causeway sub-master CWASH, placing the former one year later than CWASH (Fig.43). Both 71 and 74 cross-match well with other samples from the Causeway (Fig.43). However, the internal chronological relationships between the Causeway samples created simply by their matching position with 71/74 is not corroborated by their visual correlation (Fig.43). The sub-master CWASH also cross-matches visually with 122 of Palisade 3, a relationship corroborated by 74.

10.2.3 The Hazel

Palisade 2

Of the four samples of hazel retrieved from this context only two were usable and these did not cross-match with each other.

Palisade 3

Five samples of hazel were retrieved from this context, of which four were usable. None of these matched against each other.

Causeway

The two hazel samples from this context, 15 and 95, matched each other suggesting that 15 was felled nine years later than 95 (Fig.44).

Stakeline 1

Eight samples of hazel were retrieved from this context of which only four were usable. These four matched in pairs (Fig.44) 114 and 120 cross-matched, placing 114 two years later than 120. 116 and 119 cross-matched placing 119 eight years later than 116. 116 and 120 also cross-match visually ending in the same year and linking the two pairs.

Intra-context relationships

There were no convincing matches between sequences from different contexts.

10.2.4 The Willow

Palisade 2

Three samples of willow were retrieved from this context, of which two were usable and these did not match each other.

Causeway

Ten samples of willow were retrieved from this context of which six were usable. These all cross-matched with each other and were combined to form a sub-master CWWILLOW, 30 years in length (Fig.45). All the samples were felled in the same year.

Causeway "Floating"

None of the five samples of willow "floating" around the Causeway could be cross-matched together.

Intra-context relationships

CWWILLOW matches 75 of Palisade 2, placing 75 one year earlier than CWWILLOW (Fig.45).

10.2.5 The Alder

Only the Causeway produced alder in any quantity. Nine samples were retrieved from this context and seven were usable. Of these two pairs 3/4 and 37/38 cross-matched very well (Fig.46). 3 and 4 cross-matched with a z-value of 10.0, suggesting an origin in the same tree.

10.2.6 The Site Chronology

With so few chronological relationships generated by the intra-context cross-matching, the likelihood of constructing a reliable well-replicated chronology is small. Inter-context cross-matching produced a handful of visually acceptable matches which can be used to link the small groups of correlated sequences but, because we cannot be certain of the chronological coherence of each context any relationship can only apply to those sequences involved. Furthermore, many of the visually acceptable matches are not corroborated by a maximum z-value. The site chronology presented here is, therefore, very tentative. The relationships illustrated in the graphs have been joined to form a block diagram in Fig.47.

This indicates that segments of Palisade 3 are contemporary with segments of the central and eastern sections of Palisade 2. In these sections individual timbers have been replaced at intervals of two, five and six years. Palisade 2A was inserted in arbitrary year 46, eight years later than Palisades 2 and 3 while Palisade 1 appears to be later than all of these although by how much is unknown since the outer years of 190 and 191 are missing. Sample 151 in Stakeline 3 was inserted at the same time as repairs to the central section of Palisade 2 were being effected. The only connection with the Causeway is Sample 88 which was inserted one year after segments of Palisades 2 and 3 were built. The intra-context correlations of the ash sequences indicate that the Causeway ash was felled one year earlier than the ash samples from Palisade 2 while the willow correlations indicate that the Causeway willow was felled one year later than the willow sample from Palisade 2.

10.3 The SORT.STRING approach

The oak, ash, hazel and willow data-sets were all run individually using the SORT.STRING program but none produced strings longer than seven sequences. The oak produced strings of six and the ash produced strings of five but none of these were examined further.

10.4 Discussion and Conclusions

The SORT.STRING results highlighted the absence of any large internally consistent group of sequences at Moynagh Lough and the traditional results have corroborated this.

Visual cross-matching has drawn together several large groups including the Causeway ash and willow and the sequences constituting SUBPAL2, all of which are acceptable on visual grounds, although obviously not internally consistent. However, in general, visual cross-matching has only succeeded in correlating small groups, often only pairs and, as a result the overall site chronology is weak and unreliable. Furthermore, those chronological relationships which are acceptable both visually and statistically are those which might have been as easily surmised on archaeological grounds alone ie. that groups of samples from the same context were felled at the same time. In other words, this exercise has contributed very little to the understanding of the construction history of the site.

Palisade 2 is an example in case. On archaeological grounds it would be interpreted as a single phase construction but it displayed very little correlation especially between samples from different sectors along its circumference. Other variables of the ring-pattern were examined for differences between the sectors. While there is very little difference in mean sensitivity around the circumference there is a marked difference in the age structure of the central and Eastern sector, the latter being built of younger material, much of it less than 26 years of age (Fig.48). However, whether this is due to exploitation of two different woodlands while building the Palisade or whether one sector represents a later repair are questions which cannot be resolved with the material available.

CHAPTER 11 THE CONSTRUCTION OF THE SITE CHRONOLOGY FOR OAKBANK CRANNOG

11.1 Introduction

As with the assemblage from Moynagh Lough, the Oakbank assemblage was subjected to both traditional and SORT.STRING procedures. The results are described according to species.

11.2 The traditional approach

11.2.1 The Alder

161 samples of alder are listed according to context in Table 2. Only 133 were eventually used. 18 samples were under 15 years of age; two samples were unmeasurable; and, in eight samples, the radii could not be matched together.

For ease of handling the material was divided into three groups, the piles, the horizontal timbers and G6, the Extension piles, and initial cross-matching took place within these groups. Very few good visual matches were found within the contexts. More often the within-context relationships were generated by cross-matches with sequences from other contexts. The results are therefore presented according to the Blocks of sequences which matched together well rather than by context. In Figs 49 to 61, illustrating the Blocks, those sequences that occur in more than one Block, and thus provide the connection for the eventual site chronology, are denoted by a broken line or by hatching.

The Piles

Eight Blocks of matching sequences were generated by the visual cross-matching. The z-values given in Tables 9 and 10 are the highest values for those positions of match illustrated in the graphs. Block 2 is strongly consistent, with only one pair not producing the highest z-value at the illustrated position. In Blocks 6 and 7 all the sequences also match each other. In the other Blocks each sequence matches with at least one other sequence at the position indicated by the highest z-value.

Blocks 1 to 5 are all linked by sequences held in common; 384 and 179 link Blocks 1 and 2; 499 links Blocks 2 and 3; 349 links Blocks 3 and 4; and 420 links Blocks 2 and 5. The resultant chronology is illustrated as a block diagram in Fig.67. The outermost rings of the samples are spread over a 13-year period, with no apparent phasing. In Blocks 6,7 and 8 the outermost rings are also spread over a number of years.

The Horizontal Timbers

Eight Blocks of matching sequences were also generated by visual cross-matching within this group. Many of the cross-matches arrived at by visual means also generated the highest z-values (Tables 13 to 15). In all the Blocks the majority of sequences match with at least two, and sometimes three, other sequences. Blocks 9 to 13 and 16 are all linked by sequences held in common. 520, 522 and 585 link Blocks 9, 10 and 12; 313 links Blocks 10 and 11; 460 and 490 are common to Blocks 13 and 16; and 309 links Block 16 with Block 10. The resultant chronology is illustrated in Fig.67. The outermost rings of the samples fall over a 21-year period, again with no apparent phasing. The two unconnected Blocks, 14 and 15, display a similar picture. The outermost rings of the two samples from G4 in Block 14 are separated by six years while, in Block 15, the three samples from G1 are separated by nine years.

The Extension Piles

Six Blocks of matching sequences were generated by visual cross-matching within this group. None of these Blocks contained any sequences in common and are, therefore, dealt with separately.

Block 17 This consists of 13 sequences, all characterized by a narrow signature year at arbitrary Year 30 (see Fig.59). Each sequence matched with at least four other sequences, giving the highest z-values for the illustrated position of match. The outermost years of this Block are spread over a 13-year period although the outermost year of eight samples falls in the same year.

Block 18 This Block consists of five sequences, all slightly longer than those in Block 17 (Fig.60). X1 matched every other sequence in this group, giving the highest z-value for the illustrated position of match. The other sequences matched with at least one other sequence. The outermost ring of all the sequences falls in the same year with the exception of X12a which falls one year later.

Block 19 Four of the longest sequences from the Extension form this Block. They all match at least one other sequence, giving the highest z-value for the illustrated position of match, although X15 matches every sequence in the Block (Fig.60). The outermost year of all sequences falls in the same year with the exception of X9 which falls one year earlier.

Blocks 20-22 These Blocks all consist of pairs of sequences which match well both visually and statistically (Fig. 61). Block 22 consists of the two willow samples from the Extension, X7 and X8. Within each Block there is a difference of one year in the outermost year of the two sequences.

The Site Chronology

Sub-masters were created for each Block and these were then visually compared against each other. The results are presented in Figs 62 to 66. As discussed above Blocks 1 to 5 are linked by sequences held in common, as are Blocks 9 to 13 and 16. Blocks 7 and 8 cross-matched visually well with Blocks 1, 2 and 5,thus incorporating them into the Piles chronology (Figs 62 & 63). Block 6 cross-matched visually well with Block 7 but not with any other of the Blocks (Fig.62). Block 13 and Block 16 also cross-matched well with Blocks 1, 2 and 5, thus drawing together the Piles and the Horizontal timbers (Fig.63). Within the Extension timbers Blocks 18, 19 and 20 cross-matched visually well together but could not be correlated with Blocks 17 and 21 (Fig.66). However, Block 17 matched Block 7 extremely well, giving a z-value of 4.8, thus linking the Extension with structures in the main body of the crannog (Fig.64). Where the Block sub-masters that cross-matched well together came from contexts which had not previously been compared ie. between Horizontal, Piles and Extension, constituents of each Block were compared. The constituents of Block 17 and Block 7 correlated extremely well, both visually and statistically, and an example is illustrated (Fig.65).

The site chronology, summarized in Fig.67, is discussed in Chapter 14.

11.2.2 The Oak

54 samples of oak were retrieved from the excavated portion of the site. 13 samples were either too small or unmeasurable. The remainder ranged in age from 18 to 138 years. Because all the samples were roundwood, the complete cross-section of the tree was available for observation and it was clear that, on the majority of the samples, the growth-pattern was assymetrical around the circumference of the stem.

Wherever possible two radii were measured, cross-matched and then combined to form a stem-master, in the belief that this would minimise inter-stem "noise". However, visual cross-matching between the radii from the same stem was very poor, as reflected by the low t-values for the radial matches (Fig.68).

Although many of the older samples had lost their outermost rings because of erosion and abrasion, most of them retained a small amount of sapwood. The presence of relatively long sequences retaining the heartwood/sapwood boundary (H/S) augured well for the construction of a site chronology. However, visual cross-matching of the oak sequences proved to be very unsuccessful.

Within F16, the context producing the greatest number of long oak sequences, only two pairs 370/93 and 372/84, matched visually well (Fig.69). In both pairs the H/S boundary of each sequence fell within the 68% confidence range of ±9 years but the erosion of their outermost years prohibits any statement about their contemporaneity.

Within F17 three sequences, 328, 336 and 356 cross-matched visually well and were combined to form a sub-master F17OAK, 77 years long (Fig.70). Although this places the outermost year of 336 15 years later than the outermost year of 356 and 328, the H/S boundary on all three samples falls within the 68% confidence range of ±9 years, suggesting the possibility that all three samples were felled at the same time. However, this range is also present <u>within</u> the stems of 356 and 328. Only one other sample, 542 from F24, cross-matched well with the sub-master F17OAK (Fig.70). The bark edge was present on this sample, indicating that 542 had been felled 35 years earlier than F17OAK.

11.2.3 The Hazel

23 samples of hazel were retrieved from the excavated portion of the site and, of these, 14 samples were usable; the remainder being either too short or unmeasurable.

Of the few sequences that matched visually well only one sequence, 564, had its outermost rings. On all the other samples the outermost years were eroded (Fig.71).

11.3 The SORT.STRING approach

Only the alder generated strings of sequences greater than six and so this is the only species from Oakbank crannog submitted for analysis using this approach.

11.3.1 The Alder

The 133 alder samples were submitted to the SORT.STRING program and four mutually exclusive Targets were sorted out. Method 3 was followed so the constituents of each Target and its Extension were combined to form a sub-master and then run against the residual data-set. The results discussed below.

Target 1

There were originally 15 sequences in this Target and its Extension Figs 72 & 73). However, one sequence, X9, contained a group of very narrow signature years early in its ring-pattern and was excluded for this reason. In the subsequent cross-correlations it was not re-sorted. A further 33 sequences cross-matched the sub-master in strings greater than six and all have overlaps greater than 15 years with no coincidence between extreme values.

Target 2

There were originally 16 sequences in this Target and its Extension (Figs 74 & 75). However, one sequence, X5, contained a very narrow year-ring towards the end of its ring-pattern which had caused the erroneous matches against the modern alder (see Chapt.9). It was therefore omitted from the sub-master but was subsequently cross-matched against the former in its original position. A further 29 sequences cross-matched the sub-master in strings greater than 6 and all have overlaps greater than 15 years with no coincidence between extreme values.

Target 3

There are 17 sequences in this Target and its Extension (Figs 76 & 77). The sequence X9 was included in this Target because the presence of 2 other long sequences would reduce the effect of the narrow signature years in the ring-pattern of X9. 13 sequences cross-matched with the sub-master in strings greater than six. However, visual corroboration revealed that, although these sequences had overlaps of greater than 15 years they all have a narrow year-ring aligned with the narrow year-ring at Yr 10 in the sub-master (Fig.x). The coincidence of these two rings in each case had dominated the statistical correlation and visually none of these matches are acceptable.

Target 4

Target 4 contains only seven sequences (Figs 76 & 78) and when run on the SORT.STRING.EXT program, no Extension sequences were found that matched at least six of the Target sequences. This Target was therefore not processed any further.

The site chronology

The next stage in the analysis was to merge the four Targets and their groups to form the overall chronology. However, there were many sequences held in common between the groups and, consequently, there were several in conflicting chronological positions. The conflicts were resolved in the following manner;

Some five sequences, X20, X26, 585, 600 and 520, were held in common between the Targets and their Extensions, thus forming links between the Targets (Fig.79). As the sequences in the actual Target and its Extensions have the highest probability of being correct their chronological position took precedence in any conflict. The groups were then compared and any sequence which occurred in more than one position was eliminated. 68 sequences were finally included in the site chronology, which is illustrated as a Block diagram in Fig.69. The probability levels are indicated by shading; those in the Targets and their Extensions have the highest probability; those matching more than one Target sub-master have a high probability level while those which only match one Target sub-master have the lowest probability. Given that we can expect an error ratio of 1:10 it is likeliest that the error would occur in this last group.

11.4 Analysis and Interpretation

The few oak and hazel samples that actually matched can contribute nothing to a site chronology because, in almost every case, the outermost years were missing. Analysis will, therefore, concentrate on the alder chronologies. Two have been constructed, one using a more traditional approach, the other using the SORT.STRING approach. In this section I propose to describe each chronology and then compare the two together.

11.4.1 The traditional site chronology

66 sequences are included in the overall site chronology which spans 93 years (Fig.67). It indicates deposition and renovation over a period of 37 years from arbitrary Yr 58 to Yr 94. The horizontal timbers in F17, F24 and G5 were the earliest to be deposited. Horizontal timbers in G1 and G4 are deposited later but at the same time as the first repairs to the piles are being carried out. Pile replacement begins in Yr 71 and appears to be very piecemeal, a few piles being repaired each year. In Year 82 the Extension to the crannog is either built or is extensively repaired. Apart from this there are no major phases of repair in this chronology. Deposition of horizontal timbers stops in Yr 78 but replacement of the piles is constant over a 13-year period until Yr 83. There is a "passive" phase for nine years when nothing is done to the structure, then another few piles are replaced. In Year 93 piles in the Extension are replaced.

11.4.2 The SORT.STRING chronology

68 sequences are included in the overall site chronology which spans 78 years (Fig.79). There is activity over a 47-year period from Yr 32 to Yr78. Apart from a single pile in Yr 32 nothing happens until Yr 38 when a group of horizontal timbers in F17 are laid down. From Yr 38 until Yr 53, horizontal timbers are deposited and piles replaced on a yearly basis. In Yr 47 there is a major phase of construction when ten of the Extension crannog piles are positioned. Deposition of horizontal timbers ceases after Yr 51 and after Yr 53 activity on the crannog is more sporadic. Piles in the main body of the crannog are replaced in Yrs 57, 59, 67 and 75. Between Yrs 65 and 70 there is some repairs to the Extension crannog and, finally, in Yr 78 one of the basal horizontal timbers in G1 is deposited.

11.5 Discussion and Conclusions

The two chronologies appear to tell a very similar story. Both indicate an active period over 16 years during which repair and deposition occur annually. Neither shows any major building phase nor do they indicate any clear separation into the "lower" F24 timbers and "upper" F17 timbers. However, if the internal relationships of each chronology are compared it is apparent that, while small groups of sequences maintain identical inter-relationships in both chronologies, the majority lie in conflicting positions relative to each other.

This situation begs several questions. Do we simply abandon this attempt at chronology construction or do we choose one chronology in preference to the other? The modern alder chronology has demonstrated that we can expect some success in correlating alder sequences but how do we judge which chronology is the "correct" one? Ideally all the relationships within a chronology should be supported by both statistical and visual corroboration. Statistically-determined correlations alone can pick up erroneous matches as was demonstrated by the Test 3 results, while visual correlation alone is a subjective procedure. However, even in the most robust long oak chronologies the ideal situation does not exist so, in assessing the two alder chronologies we should look for the best combination of visual and statistical agreement.

The SORT.STRING chronology should be statistically robust since all relationships within this chronology were initially determined by the maximum z-value between the sequences. The Targets and their Extensions are the most strongly consistent but, with the inclusion of every additional sequence, consistency is weakened. However, even within the Targets the statistically-correlated sequences often display poor visual agreement although there are also small groups of visually acceptable matches (Figs 73, 75, 77 & 78).

These small groups of visually acceptable matches are, on the whole, those which constitute the Blocks in the traditional chronology. In the latter the internal relationships of each Block were determined by their visual agreement and, although this is subjective and the results could be contested by other workers, many of the original Blocks are also supported by strong statistical consistency (Tables 9 to 13).

Consequently, most of the relationships within the Blocks are corroborated by the SORT.STRING results. Only 15 pairs of correlated sequences, listed in Table 14, common to both chronologies, are placed in different relationships within each pair and, of these, nine pairs are found in the optimal visual and statistical position within the traditional chronology. It is when the Blocks are merged to form the site chronology that further conflicts between the two chronologies are introduced. I must conclude that the only reliable correlations are those found between small groups of sequences, found mainly in Blocks 1-22.

CHAPTER 12 THE AGE STRUCTURE AND TREE-RING CHARACTERISTICS OF MODERN COPPICE

12.1 Introduction

In Chapter 7 I proposed to examine the age structure of a sample of modern coppice to facilitate the construction of an operational model for woodland exploitation. Hazel and alder were the species selected. In addition to analysing the age structure of both species, the tree-ring attributes of the alder were also to be examined as part of the larger study into the dendrochronological potential of alder. Consequently, I required a sample of hazel cut on a traditionally short cycle and a sample of alder similar in age to the fossil alder and the unmanaged moden alder from Loch Tay.

Suitable samples were found in Bradfield Woods, near Bury St Edmunds, in Suffolk. Apart from a short hiatus in the 1960's the woodland has been managed under the classic "coppice-with-standards" system since the 13th century (Rackham, 1980). Standards are generally oak and ash but the understorey is a highly varied mixture of species, alder, hazel, birch, ash, maple, lime, elm etc. The composition of the understorey reflects the great variability of the woodland soils which range from acid sand to alkaline clay over a matter of yards.

Although I had the specific requirements outlined above, I was constrained in my sampling by the cropping program in operation in the woods. Consequently four stools of 24 year-old alder coppice were sampled in June 1985 and a further 16 stools of 10 year-old hazel were sampled in November 1985. All living stems on the stool were felled and a small section was removed from the base of every stem.

12.2 The Hazel Coppice

In all, 266 stems of hazel were sampled. The age structure and age/size relationships of the whole data set are illustrated in Fig.80. Anything from six to 30 stems were sampled from a single stool and they ranged in size from 0.5cm to 6.5cm in diameter. Surprisingly, only 54% of the total sample were 10 years old, the length of the coppice cycle. The age of the stems precluded reliable cross-matching so it was impossible to say whether the spread of younger material represented new shoots growing during the course of the cycle or stems whose growth had been suppressed. However, the presence of two 11 year-old stems, which were presumably 1 year-old shoots missed in the previous felling, suggests that growth of new shoots does occur during the course of the coppice cycle.

12.3 The Alder Coppice

22 stems of alder were sampled, the four stools producing three, six, six and seven stems respectively. The age structure and age/size relationships of the entire sample are illustrated in Fig.81. The stems ranged widely in size, varying from 3cm to 16cm on the same stool. At least 13 stems, or 59% of the total sample, were 24 years old, the length of the coppice cycle. However, assessment of the age structure is complicated by the presence of at least five samples with compressed outer rings, thus preventing exact ageing (see Chapt.8). The remaining four samples were 8, 8, 15 and 17 years of age respectively and appeared to have a full complement of growth rings. However, the ring-sequences of all these samples, including those with incomplete sequences, show a clear pattern of suppressed growth, beginning soon after the onset of growth (Fig.85). Furthermore, where it is possible to match the ring-sequences they all start on the same year. It seems

most likely, therefore, that these were shoots whose growth had been suppressed by the more dominant stems, (see Chapt 8) rather than new shoots that started growth during the coppice cycle.

12.3.1 Cross-Matching

The ring-patterns of the alder samples were also examined. The ring-patterns of two radii on every stem, except the four youngest samples, were measured and cross-matched. The t-values for these radial matches were compared against those of a data-set of similar age selected from the modern unmanaged alder from Loch Tay (Fig.82b). The t-value, as a measure of the similarity between ring-sequences, is also a measure of the symmetry of the growth-rings around the stem. In theory, the controlled growth of alder in a coppiced woodland should lead to greater symmetry, and therefore larger t-values, a feature which might be useful in distinguishing coppiced material in an archaeological assemblage (in conjunction with other characteristics, of course). In practice, however, there is a large overlap between the t-values for the coppiced alder and those for the unmanaged, lochside alder. The largest values do occur for the coppiced alder but the boundary between the two data-sets is too close to provide any useful criteria for distinguishing between them. The resultant 18 stem-masters were also cross-matched against each other using the SORT.STRING program. 13 sequences were sorted out in their correct positions in one string. The remainder were those samples with incomplete, suppressed ring-patterns. Two of these were sorted in subsequent, shorter strings but three sequences were not sorted at all.

These results tend to support the conclusion reached in Chapter 9, that only alder with strong dominant growth patterns are susceptible to cross-matching.

12.4 Discussion and Conclusions

"All the rods of any one batch thus have the same number of annual rings, but vary in diameter according to the good or bad conditions in which each rod grew" (Rackham, 1977, 67). The present analysis of the modern coppice has demonstrated that this is not necessarily the case. Just over half the hazel stems were the same age as the coppice cycle and the remainder, with the exception of the two 11 year-old stems, were younger. The presence of samples with partially unmeasurable ring-sequences in the alder coppice means that the age structure of this data-set is unreliable.

As described in Chapt 7 the hurdle-maker would work within the area of coppice selecting out from the freshly-cut stems those of the requisite size. This process was simulated in the modern sample by selecting out all stems of between 2.5cm and 4cm diameter (Fig.82a). Their age structure is no different from that of the entire data set and it follows that a hurdle constructed using this material would have a similar age structure, namely a peak of the oldest material with a tail of younger material.

In contrast, the age structure of some of the Somerset trackways display a wide spread of ages on either side of a peak (Fig.83). Several explanations have been put forward for these distributions. Morgan has argued that the position of the sample along the stem would have varied and, given the conical nature of tree growth, this would account for some of the variability (Morgan, 1978, 82). This supposition was tested on the modern alder coppice by sampling at intervals up the stem. It was estimated that, on stems of the lengths recorded at Tinney´s and Rowland´s Tracks, up to five year-rings could be "lost" by variable sampling, thus accounting for the presence of some apparently younger material but not, however, for the older material (Crone, 1987). Morgan (pers. comm.) suggests that some, at least, of the larger material is derived from pegs and timbers not actually forming part of the hurdle frames which, with hindsight, should have been analysed separately.

The wide variation in age together with a relative clustering in size displayed by some of the Somerset Levels trackways (Fig.84) led Rackham (1977) to suggest that stems of the requisite size were selectively felled from the stool, leaving the remainder to grow on and resulting in stools growing stems of all ages. If this were the case it would clearly be impossible to calculate a coppicing cycle from such material. However, in practice it is extremely difficult to select out stems while still attached to the stool, regardless of whether the axe is stone or metal (Coles & Darrah, 1977). It is more efficient to fell the whole stool and then select from the felled material. Thus the stool would never yield stems older than the length of the coppice cycle.

If the age/size characteristics of the material used in the hurdle and brushwood trackways of the Somerset Levels do not conform to those of the modern, formally coppiced material studied here and the arguments outlined above do not adequately explain the divergences, how, then are we to interpret the assemblages? Much of the wood displayed those macroscopic features characteristic of coppiced wood together with distinct concentrations in a number of age groups. In the operation model outlined in Chapt 7 a combination of these features indicates the exploitation of adventitious coppice. I propose here that, given the present state of knowledge, this is the optimal explanation for many of the Somerset Levels trackways. In this respect it is interesting to note that, in summarising her work in the Somerset Levels, Morgan has, in the light of this recent research, latterly begun to talk about "..woodland (being) exploited at an informal and probably irregular level.." (Morgan, 1987, 127), of "..cutting from stools which have been cut over before." (Morgan, 1987, 188).

CHAPTER 13 THE EVIDENCE FOR WOODLAND MANAGEMENT ON THE CRANNOGS

13.1 Introduction

The length of the coppice cycle and hence, the size of the stem, depends very much on the function to which the material is to be put. The small flexible stems of the modern hazel coppice would be most suited to use in hurdle screens and wattle-and-daub walls while the larger stems of the alder coppice would be useful as fencing, and as structural timbers. The modern alder coppice is, in fact, comparable in diameter to the palisade timbers from Moynagh Lough and to the piles and flooring at Oakbank Crannog. It might, therefore, be considered a legitimate exercise to examine all timbers on both sites for evidence of coppicing. However, the lack of success achieved in phasing either site must necessarily restrict such an investigation. To assess the age structure of Palisade 2 at Moynagh Lough in terms of woodland management ignores the possibility that some of the wood might represent later repairs and refurbishments which have not been detected. Investigation is therefore limited to the hurdle screens, structures which are traditionally built using coppice material and which clearly represent a single constructional event. No such screens were recovered at Oakbank Crannog. At Moynagh Lough a hurdle screen, F350 was uncovered together with an area of interwoven wood, F307.

13.2 F307

Description

F307 originally appeared to be a single hurdle, lying just inside the palisade and cut by a cesspit on its S. edge (Fig.4). The deposits overlying F307 were being spaded off and some damage was done to the wood before it was recognised as being interwoven. It was c. 1.0m wide and extended for c. 2.40m although both ends were extremely fragmented. Only two sails were visible upon exposure but another four appeared as the withies were lifted. The sails did not seem to be that well-integrated with the withies. The withies themselves were branches, often untrimmed, wound in and out of the sails in a very haphazard manner. No 'heels' or other physical characteristics indicating coppicing were found. A line of 18 small stakes lay _in situ_ at intervals of between 10-20cm along the S edge of the wattle screen. They could not be aligned with the horizontal sails as they lay further to the E. The hurdle at the E end was quite different in appearance, the withies being stouter and more regular. The withies were sampled in four blocks from W to E to test the possibility that F307 was, in reality, two hurdles.

Analysis and Interpretation

144 withies were sampled together with the six horizontal sails and the 18 stakes. All the sails and stakes and 56% of the sampled withies were identified as to species, their growth-rings counted and their diameters measured. These attributes are illustrated in Figs 86 and 87, according to block.

The age/size relationships within the four blocks show a marked change from W to E (Fig.86b). The withies at the W end are generally of smaller, younger wood while those at the E end are marginally older and larger. A similar division is seen in the species composition (Fig.86a). The withies at the W end are almost entirely hazel while at the E end a large proportion of _Prunus_ species and members of the Pomoideae family (see below for explanation) are also included. The analysis tends to support the hypothesis that two separate hurdles, a flimsy, badly made hurdle at the W end (F307A) and a stouter hurdle to the E (F307B) were inadvertently sampled. The two hurdles overlap in Blocks 2 and 3 but were not separated by any distinct layer. This obviously complicates any analysis of the age structure of the two hurdles. However, if Blocks 1 and 4 are taken as representing the separate hurdles they display a spread of ages untypical of formally coppiced material (Fig.87a). The sails and stakes, which were all hazel, display a similarly wide spread of ages (Fig.87b). The size range of all the material is quite restricted (1-2.5cm) and it must be concluded, on this evidence, that the hurdles were built using wood selected on the basis of size from unmodified woodland.

13.3 F350

Description

F350 lay immediately in front of Palisade 2 and appeared to be associated with the inner Palisade 2a (Fig.3). However, upon excavation the hurdle was seen to be lying against and over the sloping stakes of the palisade. The hurdle was stout and well-made, covering an area 3.0m x 1.60m, although its full extent was not uncovered. A pole of oak lay across the hurdle, on the same axis as the withies but not woven into them. Six paired sails lay at intervals of 0.4-0.5m. The members of each pair were approximately 0.8-1.0m long (although their full length was not exposed as the S edge of the hurdle ran into the baulk) and did not extend the full width of the hurdle but overlapped in the middle. 25-30 ′courses′ of withies were exposed, weaving alternately around the sails. Occasionally a bunch of two to three withies would pass in front or behind two adjoining sails. The slashed ends of the withies were always caught behind a sail. Where their full length could be traced the withies were between 1.0-1.3m in length.

Analysis and Interpretation

All the sails were sampled and analysed while 47% of the sampled withies were analysed. The age structure, age/size relationship and species composition are illustrated in Figs 88 and 89.

The sails are generally older and larger than the withies, ranging in age from 12 to 29 years, while the bulk of the withies are under 10 years of age. The age structure of the withies is very similar to that of the Tinney's Ground alder (Fig.83), with a concentration in numbers between five to eight years. Much of the wood had the straight-grown, branch-free morphology of coppiced material and this fact, together with the predominance of a number of ages in the material suggests the exploitation of adventitious coppice, which is being cut over irregularly over a number of years.

This interpretation is supported by the variety of species used in the construction of the hurdle. Nine species were used (Fig.89); even the paired sails were of two different species. Traditionally hurdle screens are built using one, possibly two, species, hazel, alder or willow providing the most flexible material (Edlin, 1974). Consequently, in formally managed woodland, these species were encouraged to the detriment of other less useful species until pure coppice stands arose (Edlin, 1974). In stands of adventitious coppice arising after virgin woodland has been felled, one might expect the mixture of species present in hurdle F350.

13.4 Discussion and Conclusions

The evidence presented above suggests that the materials used in the construction of the hurdles at Moynagh Lough did not originate in formally managed woodland. I have suggested, on the basis of the evidence from the modern coppice samples and my subsequent re-interpretation of the Somerset Levels assemblages, that the wood used to construct Hurdle F350 originated in areas of adventitious coppice. The lack of any concentration in age in Hurdles F307A or B, together with the "twiggy" morphology of the wood itself, indicates an origin in unmodified woodland.

The evidence from Moynagh Lough complements the lack of direct documentary evidence for woodland management for that period but leaves the question as to the manner of woodland exploitation unanswered.

Apart from considerations of coppice management, the hurdles from Moynagh Lough contain a number of features worthy of comment.

Most of the species found in the hurdles also occur amongst the larger timbers from the site. The most notable absence is that of ash which forms 15% of the total site sample yet there is only one piece used in the hurdles. Either two different woodlands were being exploited, or ash in the one woodland was being left to grow to maturity to provide larger structural timbers. Prunus species does not occur elsewhere on the site. This genus covers a number of species including wild cherry (Prunus avium), plum (Prunus domestica) and blackthorn (Prunus spinosa) but identification to the exact species must rely on macroscopic characteristics which have often not survived (Schweingruber, 1978). Three pieces had thorn attachments indicating that they can only be blackthorn.

The Pomoideae group also covers a large group of species and similar problems of identification arise. On microscopic characteristics the samples from Moynagh Lough have been narrowed down to the group containing Apple (Malus sylvestris), pear (Pyrus communis), quince (Cydonia oblonga) and hawthorn (Crataegus sp.) (Schweingruber, 1978).

Eight pieces from the hurdles had thorn attachments indicating that they are hawthorn.

Both hawthorn and blackthorn would be extremely difficult to weave into a hurdle due to the thorns and crooked growth of the branches. Moreover there was no necessity to use such difficult material when numerous other species were obviously available. The description of the post-and-wattle fence contained within the 7th century law tract, the Bretha Comaithchesa, provides an explanation (O´Corrain, 1983). The uprights were to be set c.20cm apart, "...a foot to the joint of the big toe..." (O´Corrain, 1983, 248). The fence must have three bands of wickerwork, one at the base, one in the middle and one at the top, and the uprights, which must extend some 45cm above the upper band of wickerwork, should be surmounted by a "crest of blackthorn" to prevent stock jumping over it.

In the light of this description it is unfortunate that the position of samples up and down the hurdles was not recorded. In the case of Hurdle F350, the spacing of the sails does not conform to the legal description and the wickerwork extends the full length of the sails rather than forming three broad bands. The spacing of the sails in hurdles F307 East and F307 West approximate more closely to the legal standard but, again, the wickerwork does not appear in bands. The function of these hurdles is unknown and therefore the relevance of the law tracts to them cannot be gauged. Despite this, the law tracts do provide an attractive explanation for the inclusion of small amounts of thorn branches, be they hawthorn or blackthorn, in the hurdles at Moynagh Lough, possibly as a token gesture as regards these particular laws.

The paired sails in hurdle F350 are unusual. I initially thought that such construction would make the hurdle weak and unstable, thus rendering it unsuitable as an upright screen or wall (Crone, in press). However, recent excavations at Deer Park farm, Co. Antrim, have revealed wattle walls of similar construction and still in situ (Lynn, 1987). The excavator suggests that the wattle was woven to the top of the primary sails after which the upper sails were driven into the spaces in the wattle beside the lower sails.

CHAPTER 14 SUMMARY AND CONCLUSIONS

14.1 Introduction

The original aims of the present research are detailed in Chapters 6 and 7 above while the succeeding chapters detail the course of the project and its results. The purpose of this chapter is to refocus attention on the original research questions; to determine the extent to which answers to them have been provided; to explore the nature of those answers, and to highlight the indications for future work. To these ends, the two research problems are considered separately below.

14.2 Given the nature of the wood assemblages under investigation, can site chronologies be constructed?

The wood assemblages from the crannogs posed two seperate, but inter-related problems. Firstly, many species which had not previously been used to any great extent in dendrochronological studies were present on the crannogs and, in the case of alder at Oakbank, present in sufficient quantities to make chronology construction possible. Secondly, most of the timbers were under 50 years of age and most existing procedures had, on the whole, only been used on sequences of 100 years or more so that the statistical procedures employed could not be used confidently on the shorter sequences.

14.2.1 **The use of non-oak species**

Alder

As alder constituted some 62% of the wood assemblage from Oakbank crannog it promised to be the most useful species for chronology construction at that site. However, apart from Elling´s research into modern alder in Germany (Elling, 1966), its viability as a dendrochronological species has never been fully investigated. It was, therefore, necessary to analyse a sample of modern alder in order to establish;

1. whether the ring-pattern is reliable and susceptible to cross-correlation.
2. a methodology for its use.
3. its limitations.

To these ends, thirty alder trees, growing on the shore of Loch Tay, opposite Oakbank crannog were sampled. Four coppiced alder stools from Bradfield Woods, Suffolk, sampled as part of the investigation into woodland management, also contributed to this study.

Intra-sample variability

The diffuse-porous ring-pattern of alder was most easily measured under low magnification (x20) because the ring boundary, often faint in patches, is visible over a larger field of vision. As the modern alder samples were cores only two radii were available for measurement but, on each of the ancient alder samples, growth increments along three radii were measured. This was to ensure that any discrepancies in the ring-pattern would be detected during the comparison of the three radial ring-sequences. Although the measurement of only two radii on each of the modern alder samples provided reliable ring-patterns it is recommended that three radii be measured. For example, if a "markflecke", or false ring-boundary, occurs along one radius it is unlikely to occur in the same position on another radius, given that the measured radii are evenly spaced around the circumference. Comparison of three radial ring-patterns facilitates the detection of the erroneous radius whereas, with only two radii it is difficult to know whether the difference between the two ring-patterns isdue to a false ring on one radius or a "missed" ring on the other, nor is it clear which radius is in error.

The three radial ring-patterns were then compared visually and averaged together to form a composite tree-master. All the alder sequences used in this study, whether ancient or modern, are, therefore, composite masters.

Inter-sample variability

Cross-correlation of the modern alder was carried out using the SORT.STRING program, about which a fuller discussion is provided below. Its successful application to the modern alder demonstrated that alder is susceptible to statistical correlation and that the z-value, although generally low for the alder correlations, can be as powerful in locating the correct chronological relationships among alder sequences as it is when used on oak. Visual correlation was very good for the alder sample although not reflected by particularly high z-values. The successful correlation of 68% of the modern alder sequences suggests that missing rings are not a major problem in the dendrochronology of alder. However, until more work is done on alder from different localities we cannot be certain that regional problems do not exist eg. that, on all the alder from the same locality, the same ring is not missing.

Alder contains a number of features which limit its value for dendrochronology. A cursory glance at any of the illustrated alder graphs shows that signature years occur frequently in their ring-patterns, presumably as a result of alder´s sensitivity to micro-environmental fluctuations. Whilst these can facilitate cross-matching they are probably the greatest cause of erroneous statistical correlation when they occur in conjunction with short ring-sequences.

As few alder sequences are longer than 50 years, the presence of extremely narrow signature years will always be a problem. The use of a non-parametric method of comparison such as the "w" coefficient in which the direction of the year-ring alone is considered ie. decreasing or increasing in relation to the previous ring, would reduce the impact of these signature years (Eckstein & Bauch, 1969). However, this method has been found to be insensitive when used on short overlaps (Baillie, 1981). It might be more effective if modified for trend.

Many of the alder sequences exhibit strong trends which do not seem to be related simply to age and which can be useful diagnostic traits in cross-matching. Unfortunately, the CROS program, used throughout this study, filters out trends in the ring-pattern by converting the raw ring-widths to indices based on a moving average of five ring-widths (Baillie & Pilcher, 1973). This may explain why some of the correlations sorted out by the SORT.STRING program on statistical grounds display unsatisfactory visual correlations; the trend in each sequence has not been considered. More work is clearly needed on the effects of different filters on trend in alder and on the use of non-parametric methods of comparison to reduce the effects of extreme year-rings.

The length of the alder sequence will always be a limiting factor on its use in chronology construction. There is some evidence to suggest that only the ring-patterns of samples 40-60 years in age are reliable. Beyond that the ring-pattern becomes erratic, possibly due to suppressed growth. As alder rarely grows to more than 70 years (McVean, 1953) the comments on the use of short ring-sequences below are particularly relevant to this species.

Once the sequences have been correlated, and a site chronology constructed, the interpretation of the outermost year-ring becomes crucial. Unfortunately, evidence presented in this thesis indicates that the outermost year-ring measured on an alder sample may not necessarily be the year of felling, even though the sub-bark surface may be present. In 22% of the ancient alder there was a discrepancy around the circumference of the sample in the number of rings present. Clearly, rings along one segment of the circumference had become so narrow as to be undetectable. It was assumed that, by measuring three radii on every sample, the full complement of tree-rings would be recorded but there remains the doubt that, even on the radii with the fullest complement of rings, the outer year does not represent the year of felling. This doubt was confirmed in the study of the modern alder where 15% of the correlated sequences were missing as many as five of the outer year-rings. As all the stems sampled in this study were still living, it was concluded that, either the outer year-rings were too narrow to be detectable or that the tree had ceased laying down year-rings altogether. Elling's examination of German alders led him to conclude that overshadowing by more dominant trees led to a progressive suppression, and finally, cessation of growth. The evidence from the study of the alder coppice supports this. Out of twenty-two stems only thirteen were 24 years old, the length of the coppice cycle. The remainder ranged in age from 8 to 22 years in age and all displayed a pattern of diminishing ring-widths beginning soon after the onset of growth. Since some of these samples matched well with the 24 year-old samples in the early parts of their ring-patterns it was concluded that the presence of these apparently young samples was due to cessation of growth rather than growth initiated later, during the coppice cycle.

It is concluded that, by eliminating all sequences displaying a suppressed growth pattern we are thereby eliminating all those samples with potentially large discrepancies. However, none of those samples, ancient and modern, with small discrepancies in the number of their outermost rings displayed patterns of suppressed growth. At present there is no way of quantifying the problem except to say that the modern alder study indicates that, in any assemblage of alder, at least 15% of samples may have up to five missing outer rings. These samples would be easy to locate in an assemblage where the bulk of the samples fell into, say one or two major felling phases but in an assemblage from a site with a complex history of construction this phenomenon could prohibit fine chronological resolution. As a safeguard it is recommended that each phase should be represented by at least four samples to confirm its integrity and that single or paired sequences in a chronology should be given no weight in the site interpretation.

Four other species were examined in the course of this thesis but lack of time precluded a study of their modern analogues.

Hazel

A few descrepancies were noted during the measurement of the ring-pattern of the hazel samples. Like alder there were discrepancies between the number of outer year-rings along each measured radius and in a number of cases this was preceded by suppressed growth. Morgan had also observed this phenomenon in her study of modern coppiced hazel (Morgan, 1983). It was concluded that, as hazel always grows as a bushy shrub most stools will contain some stems in which growth has ceased because they have been overshadowed by the other, more vigorous stems. An example from Moynagh Lough demonstrates this point. Four samples of hazel from Stakeline 1 were cross-matched together, suggesting that there was a difference of eight years in the felling dates of the samples (Fig.44). Stakeline 1 is composed of small closely-set stakes which form the sails of a wattle screen and it is therefore difficult to envisage one or two of the stakes being replaced at irregular intervals. A more probable interpretation is that all the hazel stems were felled at the same time and those which are apparently "early" are stems whose growth was suppressed by the more vigorous dominant stems on the stool.

Willow

Similar difficulties in defining the outermost year-rings were also encountered when measuring the willow samples although six samples from the same context at Moynagh Lough were successfully correlated, indicating a single felling date (Fig.45). Given the prerequisite of four samples to a phase recommended earlier, this is an acceptable group. In this context it is interesting to note that, at Alvastra, Sweden, Bartholin has been able to pinpoint the actual season of felling for many of his willow samples (Bartholin, 1988). Such refined analysis is not possible with the samples used in this study, given the uncertainty about their outer year-rings.

Ash

Moynagh Lough was the only site to produce ash in any quantity. Oakbank produced only one sample. Ash is ring-porous and there were no problems in measuring the ring-pattern while definition of the outermost year-ring could, in most cases, be narrowed down to the season of felling. Some 48% of the ash samples were felled in the spring and 17% were apparently felled in the winter. However, all of the winter-felled samples came from the Causeway and some cross-matched with spring-felled samples from the same context indicating the same year of felling (Fig.41). There may have been two separate fellings or, what seems more likely, a single felling late in the season, encompassing trees which had commenced growth late in the season, the so-called spring-felled samples.

Cross-matching of the ash samples from Moynagh Lough has not been very successful. Apart from the group of five samples from the Causeway correlation has been possible only between groups of two or three sequences. The sequences are not complacent, a criticism often levelled at ash, and which which might explain the lack of correlation. This situation is similar to that of the ash from the Sweet Track in the Somerset Levels where small groups of ash matched each other but showed no correlation with other small groups from the same trackway (Morgan, 1984). Morgan interpreted this as evidence of different woodland sources rather than non-contemporaneity and the presence of ash samples commencing growth at different times during the year support a similar interpretation at Moynagh Lough.

Oak

As oak is the most extensively used species in dendrochronology in the British Isles it might be felt that the remarkable lack of success in matching the oak samples in the present study could contribute nothing to any greater understanding of the dendrochronology of the species. However, a number of interesting points do, in fact, arise.

In Chapter 3 the lack of success in cross-matching and dating oak timbers of 1st millennium BC provenance from Scotland was mentioned. The analysis of the Oakbank oak samples provides a possible explanation. A complete cross-section of every oak sample from Oakbank was available and it was observed that the growth pattern was very assymmetrical around the circumference of the stem. A plank converted from such an assymmetric stem would produce a ring-pattern which is unrepresentative of the tree as a whole and given the low agreement even between two radii from the same stem (Fig.68) the chances of successful correlation between trees is small. If the Scottish samples examined by Baillie were from similarly assymmetric stems this might explain the overall lack of success in cross-correlation.

Unlike the alder the combination of two radial ring-patterns from the same oak sample to form a stem-master did not create a clearer signal or improve intra-stem correlation nor did the individual radii from the same stem improve the situation. Clearly, the light of these results, strongly assymmetric samples of oak are to be avoided in dendrochronological studies.

The nature of these ring-patterns give some indication of the source of the oaks used by the crannog-builders. They do not seem to have had access to well-grown oak woodland but used either very young oaks or older oaks growing on rocky, exposed hillslopes and therefore subject to varying environmental influences on all sides. Oaks from another Scottish crannog, at Erskine Bridge on the River Clyde, exhibited similar features; the samples were either very young or displayed very erratic ring-patterns (Crone, forthcoming). It was concluded there that the crannog-builders were forced to scavenge along the river shore for isolated oaks.

14.2.2 The use of short ring-sequences

The objections to the use of short ring-sequences were discussed in Chapter 8 and are mainly statistical. The problem lies in the way the t-value is calculated; the shorter the overlap the greater the probability that an erroneous match might be selected. This problem was tackled here by designing an approach that reduced dependance on a single t-value quote which, between two short sequences, would have a measurable probability of selecting an incorrect match. Instead, reliability was by sorting strings of internally consistent sequences.

The SORT.STRING program was initially tested on three data-sets and was very successful with two of them, sorting out 61% of the modern alder and 71% of the Fiskerton oak into their correct chronological positions. The success of these test-runs demonstrated that the z-value was effective in selecting the correct relationships amongst short sequences of oak and alder and the program was confidently applied to the archaeological material.

The recommended minimum size of an acceptable, internally consistent group was set at strings of seven (Chapt 9). Of the archaeological material only the Oakbank alder yielded strings larger than seven. Four Target groups were sorted and merged to form a site chronology, a process which involved the elimination of many conflicting relationships (see Chapt 11). Furthermore, many of the correlations within the chronology were visually unsatisfactory. The only "reliable" correlations in terms of both their visual and statistical attributes were those between small groups of sequences. This apparent failure to correlate the ancient material is in stark contrast with the success and ease with which the modern alder and Fiskerton oak were processed and merits some discussion.

The presence of visually unsatisfactory correlations within the SORT.STRING results may be related to features inherent in the growth-patterning of alder which the statistical procedures built into the CROS program do not take into account (see 14.2.1 above). These are the presence of strong trends and extreme values, or signature years. The misleading influence of short sequences containing strong signature years has been noted above. It became particularly clear when, in the third test-case, modern and ancient alder sequences were combined and subjected to SORT.STRING. Five of the ancient samples, all short sequences with strong signatures, were correlated with a group of modern samples. As noted above a new statistic which ameliorates the impact of the signature ring-widths is now a clear research requirement.

However, given the success with the modern alder it seems improbable that problems of statistical comparison can have been solely responsible for its failure with the ancient material. In Chapt. 9 it was suggested that the presence of multiple targets generated by a data-set described its overall coherence. The generation of four virtually, mutually exclusive Target groups in the Oakbank alder suggests that the apparent failure of the SORT.STRING program to produce an overall chronology may lie, not in its inefficiency, but in the presence of timber of differing origins and/or differing chronological phases. These possible explanations are explored below;

Sample origins

Unlike the modern alder samples, the ancient samples may not have come from a single location. Indeed, given the quantities involved in constructing a crannog it is unlikely that the samples can have had a single source. Alder fringes much of the shoreline of Loch Tay and it would have been simple for the crannog-builders to float the felled trees across the loch. In Chapter 9 it was suggested that the success of the SORT.STRING program on the modern alder and Fiskerton oak lay partly in the presence of wood from only one or two sources, the argument behind this being that samples from the same source display strong coherence. Bartholin attributes his success in visually matching the short oaks from Alvastra to the fact that they were all felled in one forest and therefore subject to the same growth conditions

(Bartholin, 1987). More research into the nature of wood origins is required, possibly by examining the results of the SORT.STRING program for modern data-sets comprising a mixture of samples from different locations.

Chronological disparity

The apparent failure of the SORT.STRING program to correlate large groups of samples at Oakbank may simply lie in the chronological disparity of the samples themselves. In the "pile-dwelling" model of crannog construction, described in 4.2.3 above, horizontal timbers throughout the body of the crannog would be deposited irregularly over the period of habitation whilst the piles, if replaced over the same period, need not be contemporary either. It is in just such a situation that the limitations of using short ring-sequences become clear. At Fiskerton the building of a complex chronology of site construction with phases of repair and renovation was possible only because of the presence of suitable, longer sequences. The relationships between the small blocks (Figs 26 & 27) were only made tangible by the presence of a small number of interlinking sequences like 259 (78+ yrs), 93 (89+ yrs), 346 (94+ yrs) and 6 (104 yrs). Without the longer sequences the end result would have been a number of "floating" blocks, unconnected to each other, a result similar to that obtained at Oakbank.

Chronological resolution

Short ring sequences can, potentially, demonstrate the isochroneity of a structure, as at Auvernier-Saunerie (Lambert & Orcel, 1977). However, they will only give evidence of rebuilding or repair if the intervals involved are significantly shorter than the mean length of the ring sequences. For example, if using two sequences of 20 years length, minus the required overlap of 15 years, only those activities taking place over a five-year period can be located. The longer the sequence the greater the possibility of locating more constructional phases. However, even if sequences of 30-40 years were available for analysis they would be of no use if the phases of repair were as widely spaced as 20-30 years which, given the durability underwater of a species like alder, is not improbable. Here again, the role of the relatively few, longer sequences in the Fiskerton material must be noted, because they facilitated fine chronological resolution by placing the separate groups of sequences into an overall chronology. In conclusion then, the major limitation to the use of short ring-sequences lies, not in the statistical methods available, but, rather, in the actual length of the sequence in comparison with the length of occupation of the structure from which they came. They can be of use in demonstrating contemporaneity and the presence of closely spaced phases of construction and/or repair but will break down into a mosaic of apparently unrelated "floating" blocks if repairs and renovations to the structure take place at widely separated intervals.

The SORT.STRING program

In the course of this present study a new approach, the SORT.STRING approach, has been formulated and tested. The strengths and weaknesses of the SORT.STRING approach vis-a-vis traditional methods is now assessed.

1) SORT.STRING is far quicker, in operation, than the traditional methods.
2) SORT.STRING provides an assessment of the reliability of the groups of correlations which it generates because all the statistical relationships within the chronology are specified. At present it is not possible to provide a numerical estimate of the

probability levels at which these group relationships operate. This requires further research but the present study has served to define the problem clearly.

3) SORT. STRING avoids the subjectivity of traditional methods. Because all the data can be treated equally and simultaneously no pre-selection, by context for example, is required and the archaeological parameters, such as context, can be used to test the resultant chronology.

In conclusion the SORT.STRING program has proved to be simple and effective. However, the statistic on which it is based, the z-value, can select erroneous correlations. The future development of SORT.STRING requires advances in two statistical procedures; firstly in the suppression of extreme values either by numerical filtering or by exclusion (ie. data washing); secondly, the more difficult problem of estimating the probability level - and confidence interval - of groups selected by SORT.STRING must be tackled. Furthermore, the SORT.STRING program is based strictly on the maximum z-value. Recent work on modern oaks has demonstrated that there is frequently a lower t-value which indicates the true position of match (Pilcher & Baillie, 1987). In samples of between 40-60 years a lower t-value indicated the true position in 100% of the tested samples although this went down to 60% for samples of 30 years (Pilcher & Baillie, 1987, Fig.2). The role of "second-best" z-value has not been examined in this thesis but the possibility remains that many of the gaps in the traditional matrices might be filled by "second-best" z-values, thus making them internally consistent. Clearly, this is also an area for further research.

14.2.3 Site chronology and crannog construction

Moynagh Lough

The failure to construct a site chronology for Moynagh Lough means that none of the questions posed in Chapter 4 can be confidently answered. Unfortunately, there is little likelihood of further samples becoming available since most of the contexts from which the wood came were fully exposed and sampled. Exceptions are the two palisades which have not yet been fully exposed and further samples from these contexts may provide interconnecting links.

Oakbank Crannog

In Chapter 11 it was argued that the Blocks of the traditional chronology contained the optimum visual and statistical correlations but that some of the links between the Blocks were too weak to be confident of the overall site chronology. However, the individual Blocks themselves, if we accept that they contain "true" chronological relationships, display a common feature which is pertinent to the constructional history of the crannog. The spread of end-years in the Blocks is listed in Table 15. The possibility that the recorded outermost year is not the year of felling must be taken into consideration here and in Blocks 6, 7, 8, 18, 19, 20 and 21, where there is only a difference of two or three years between the outer years of the constituent sequences, I have assumed that the sequences are contemporary. Similarly in Block 17 where the outer years of twelve of the sequences fall within three years of each other, I have also assumed contemporaneity. The remaining Blocks all indicate depositional activity over a period of years rather than a single phase of activity even within a single context. For instance, in Block 13, the peripheral horizontal timbers of G4 are deposited over a six-year period while in Block 15 timbers from G1, the basal timbers in Section YQ, are deposited over an eight-year period. Replacement of the piles was similarly piecemeal. For instance, in Block 2 piles from F6 are replaced over a ten-year period.

In Chapter 4 it was argued that, in the "packwerk" model of crannog construction, all the horizontal timbers would belong to a single phase. The evidence presented here, such as it is, indicates that deposition was piecemeal, thus supporting the alternative "pile-dwelling" theory. However, until more timbers are available the chronology, presented in Fig.67, remains tentative.

14.3 Given the nature of the wood assemblages under investigation, can evidence of woodland management be detected?

In pursuance of the aim to examine woodland management practices at both sites it was decided that a clearer and more explicitly stated model of woodland management was required. To this end two samples of modern coppice were examined. This constitutes the largest such study undertaken to date. Hazel and alder were the only species examined and the examination of other species is a clear requirement for future research. A number of interesting facts emerged from the study.

Firstly, contrary to received wisdom, all of the stems on a coppiced stool were not of the same age. About half were of the maximum age ie. the length of the coppice cycle, and the remainder were younger. Whether the younger stems had begun growth later in the cycle or whether they had begun as early as those of maximum age and then ceased growth is not absolutely clear but the evidence of the alder coppice, whose longer sequences could be visually correlated, indicates that some stems stop laying down growth-rings although still living. On the other hand, the presence of two 11 year-old stems on hazel stools cropped ten years ago shows that new growth had occurred late in the previous coppicing cycle.

Whatever the reasons for the presence of the younger material on a coppiced stool it must needs be incorporated into a model for woodland management. This step requires some understanding of the mechanism whereby the stems from a coppiced stool become incorporated into a hurdle screen, the commonest archaeological artefact produced from coppiced woodland. I proposed, on the basis of modern analogy, that the hurdlemaker, working within the freshly-felled formal coppice, would have access to the produce of a single coppice cycle, and consequently his hurdle would display an age structure like that illustrated in Fig.80b, essentially the age-structure of atypical coppice stool. Even if he were selecting out stems on the basis of size the age structure would vary little (Fig.82a). Unfortunately, this is a process not governed by biological or cultural dictates but by the whim of the hurdlemaker and one could as easily argue that he might wander into different compartments of the wood in search of suitable material, thus gathering stems of varying age. Analysis of the age structure of modern hurdle screens would be valuable in resolving this argument. The wattles from the experimental screen built by workers from the Somerset Levels Project would have provided invaluable data but was apparently never aged (Coles & Darrah, 1977).

Neither of the crannogs produced much suitable material for this type of analysis. The failure to construct an overall chronology for either site meant that the assemblages could not be evaluated in terms of woodland management. Analysis was restricted to hurdle screens which clearly represent a single constructional event. Only three hurdles were retrieved, all from Moynagh Lough, and this limited evidence indicated that two screens, F307A and F307B, were constructed using material felled in unmodified woodland while the other hurdle, F350, was constructed using stems cropped from adventitious coppice (see Chapt.7). The absence of any evidence for the exploitation of formal coppice complements the absence of documentary evidence for its practice but the presence of areas of adventitious coppice suggests a more pioneering stage of settlement than the densely settled, well-ordered landscape portrayed for Early Christian Ireland (see Chapt.2).

14.4 <u>The contribution of tree-ring analysis to crannog studies</u>

The application of dendrochronological techniques to the mass of timbers available on many crannogs should have three primary objectives;

1. The absolute, or calendrical, dating of the crannog.
2. The refinement of a relative chronology for the crannog, providing data on the duration of occupation and structural development of the crannog.
3. The reconstruction of the woodland environment.

I would like to examine here the extent to which each of these objectives is attainable in the light of the results of the current research.

<u>Absolute dating</u>

The random sampling of crannogs in Northern Ireland yielded enough long oak sequences to provide the skeleton of a chronological framework for crannogs in that area (Baillie, 1979). However, the two excavated crannogs examined in this thesis yielded very few long oak sequences. Moynagh Lough produced only three samples with more than 100 rings and only one was absolutely dated (Chapt.4.2 above). At Oakbank few of the longer oak samples could be cross-correlated to form a site-master and none were absolutely dated. At present the only species that can be absolutely dated is oak and the evidence now available from these sites suggests that suitable long oak sequences are rare on crannogs. As discussed in 14.2.1 above, the crannog builders appear, in the main, to have had access only to young oaks and, in the case of Oakbank, poorly-grown, exposed oaks.

Relative dating

Young oaks constituted some 50% of the wood assemblage at Moynagh Lough but few of their ring-sequences could be cross-correlated with each other. This is somewhat surprising in view of the success of other dating exercises with similarly short sequences (see Chapt.6.5 above) and it is because of these successes that any such future exercises should not be summarily dismissed. However,this study has highlighted the limitations of using short ring sequences, limitations which the previous studies had not made clear. Short sequence correlations can be useful in demonstrating the isochroneity of a structure or part of a structure but will remain as unrelated "floating" blocks if sufficiently long sequences are unavailable to unify them.

The lack of oak at Oakbank meant that other species had to be used in constructing a site chronology. The preponderance of alder on the crannog is reflected at both Erskine Bridge crannog (Crone, forthcoming) and Milton Loch 1 (Piggott, 1953). Although it may seem rash to generalize on the basis of only three sites, these sites also constitute the three most recent crannog excavations, in which systematic analysis of the wood has been carried out and, as such, indicate that alder is a predominant component of many Scottish crannogs. This research has demonstrated that alder can be used in dendrochronological analysis and has provided a methodology for its use. Its limitations have been discussed above in fuller detail but the way is now open for its use in chronology construction on future crannog excavations.

This study has not examined other species in any detail nor has it examined the scope of cross-correlation between different species. Given the range of species present on both crannogs and the indications from this study that species like willow and hazel could be just as useful in chronological construction as alder, this is an area requiring further research.

Reconstruction of the woodland environment

This study has provided a much clearer model for the detection of coppiced material in the data-set. However, it can only be applied to those structures which are demonstrably a single constructional event ie. a hurdle screen, stretch of palisade, walling etc, and, therefore, relies on the provision of a reliable site chronology.

Other data contributing to a reconstruction of the woodland environment is very much a by-product of the process of tree-ring measurement; the observation of stressed ring-patterns in the oak samples at Erskine Bridge (Crone, forthcoming); of assymetry in the oak samples from Oakbank. None of this is easily quantifiable at present and requires more research on modern material.

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APPENDIX 1

ILLUSTRATIONS

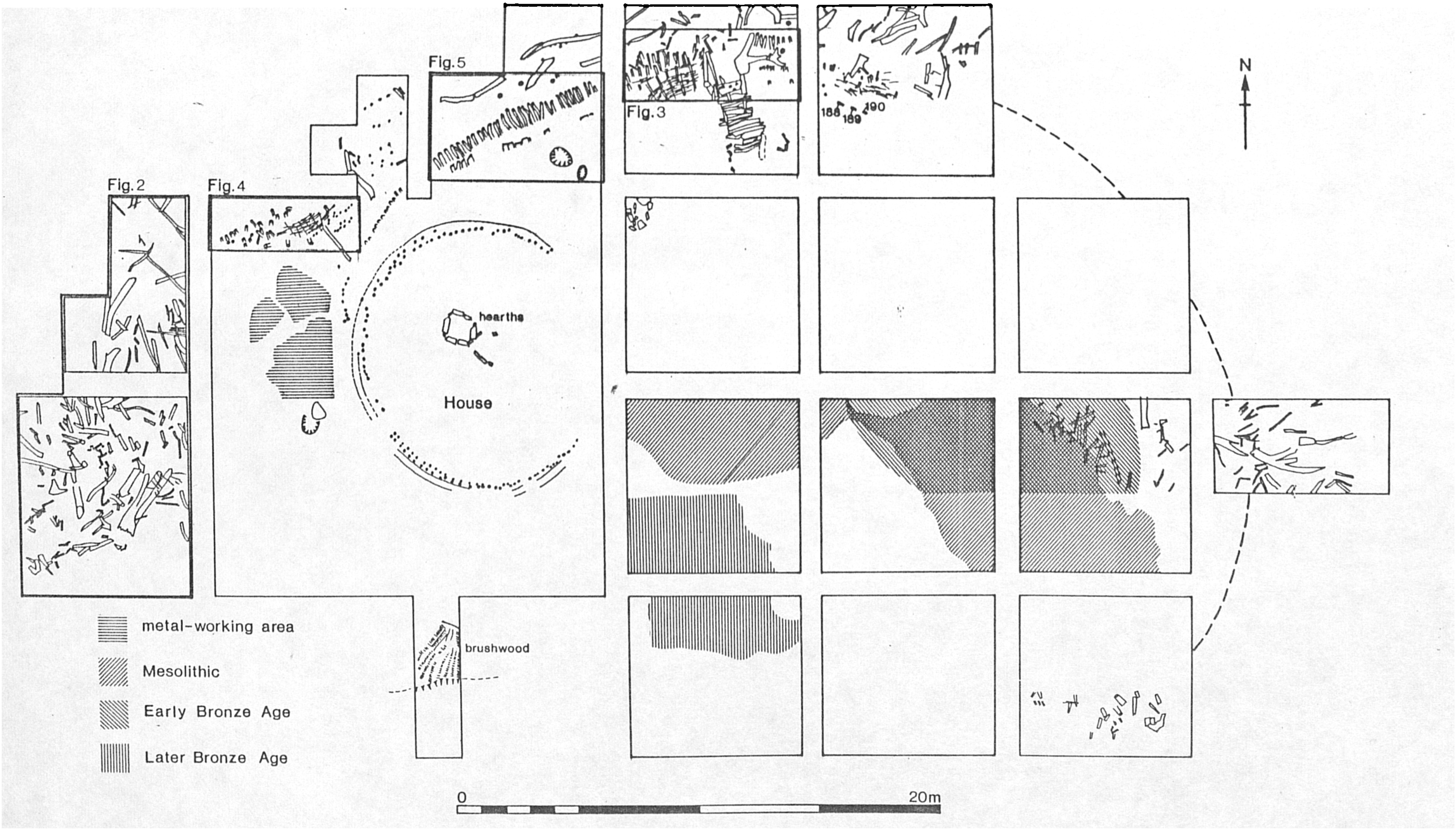


Fig.1 Moynagh Lough; site plan

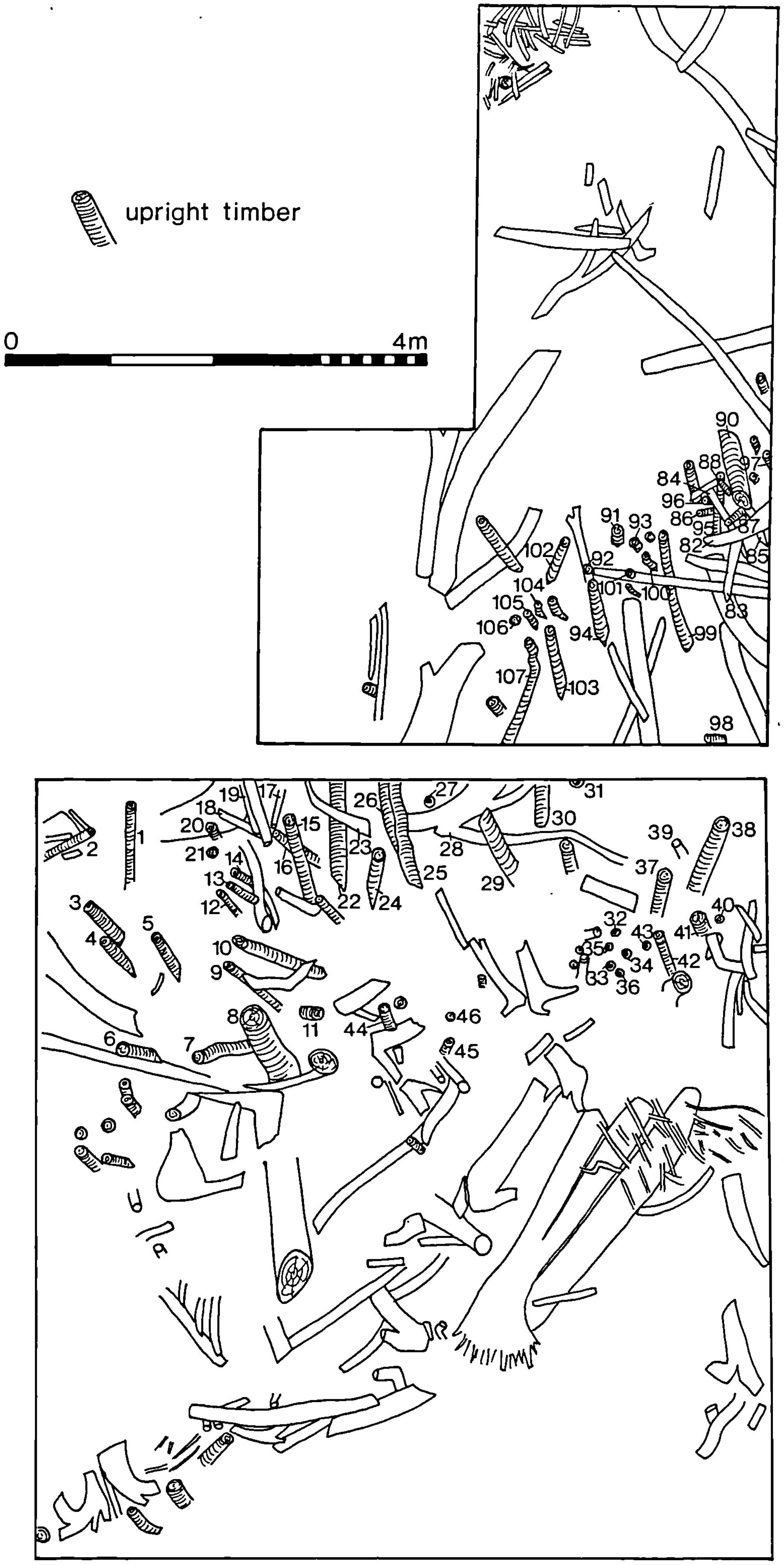


Fig.2 Moynagh Lough; the "Causeway"

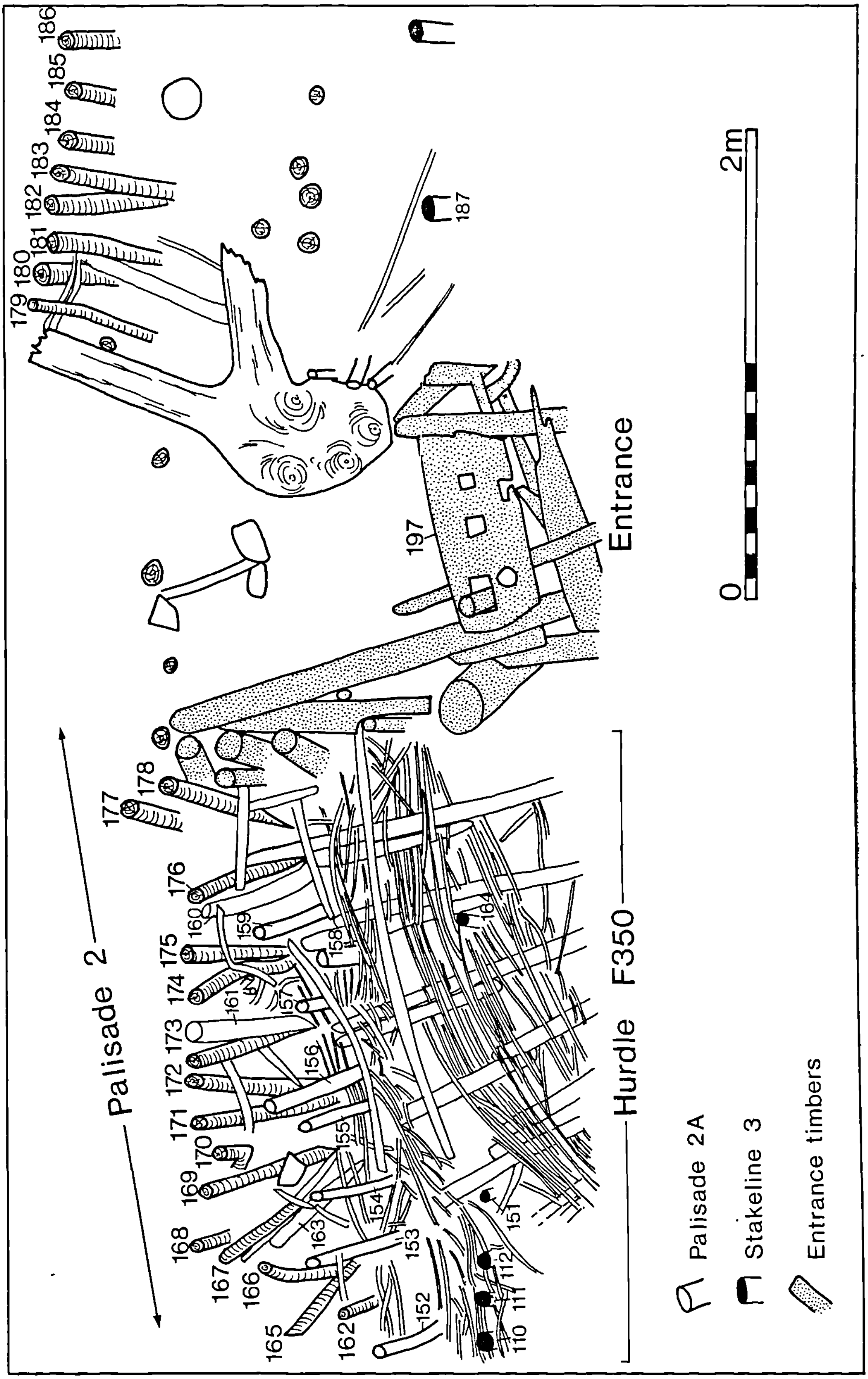


Fig.3 Moynagh Lough; The Entrance area

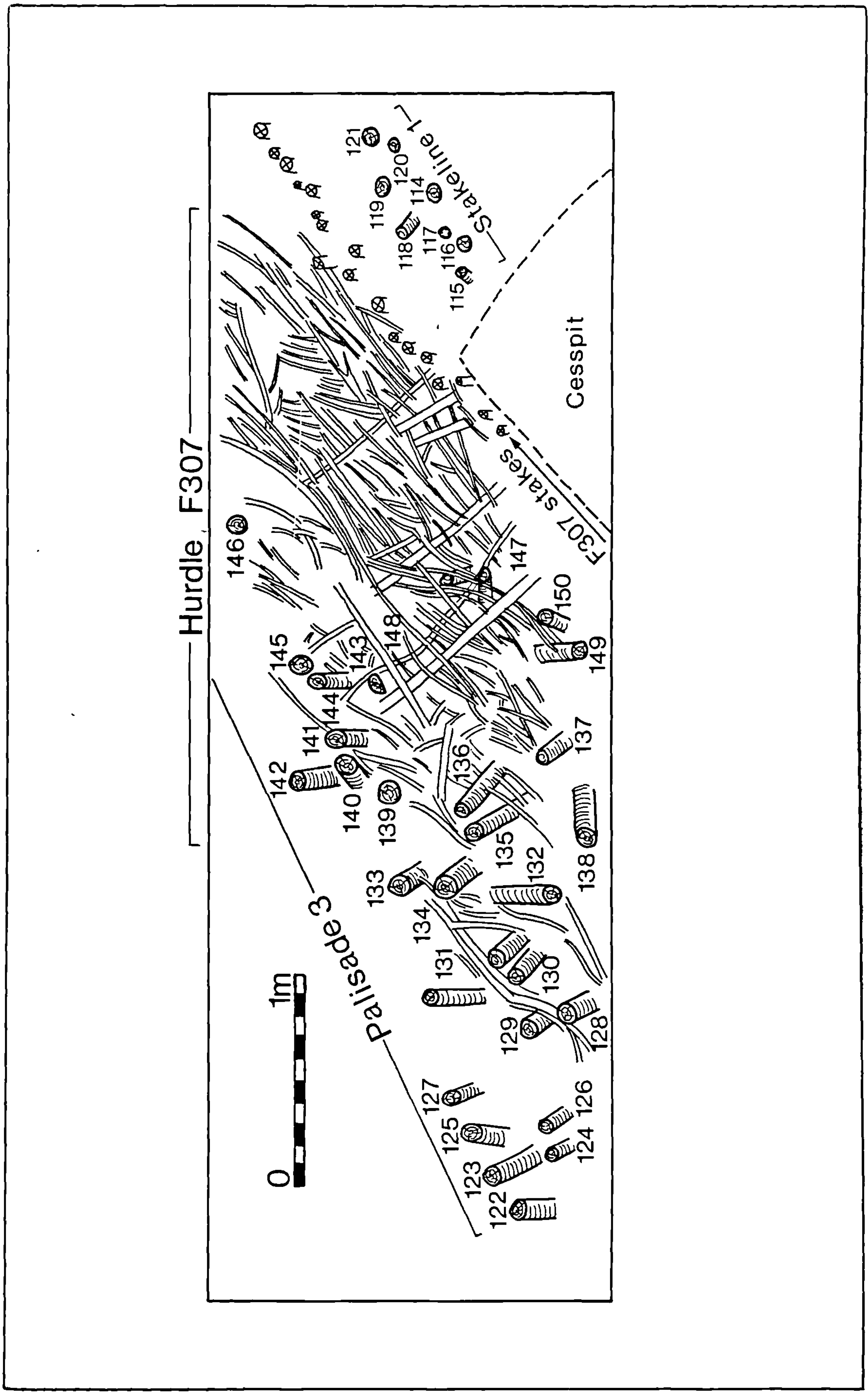


Fig.4 Moynagh Lough; Palisade 3 and Hurdle F307

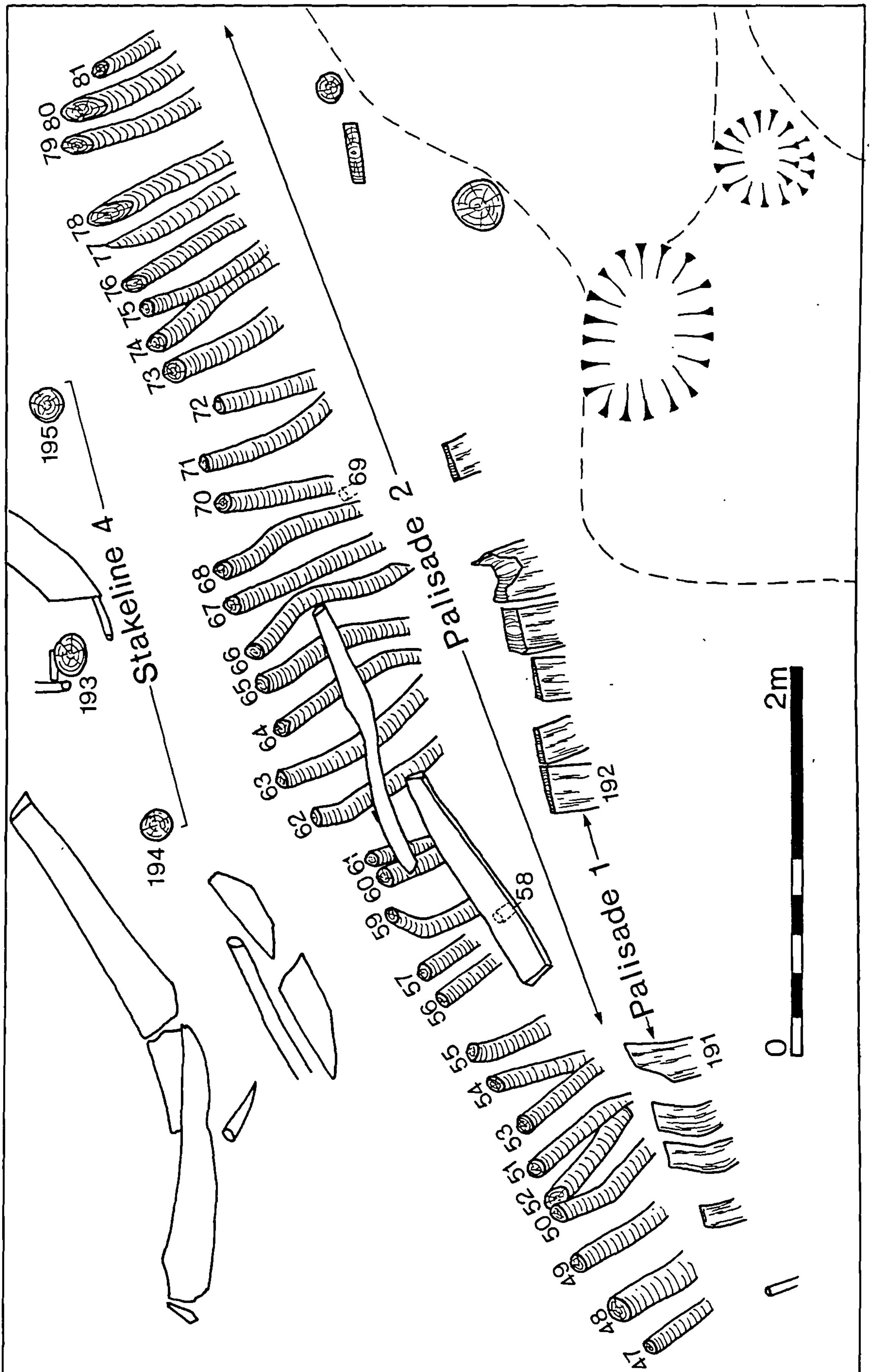


Fig.5 Moynagh Lough; Palisades 1 and 2

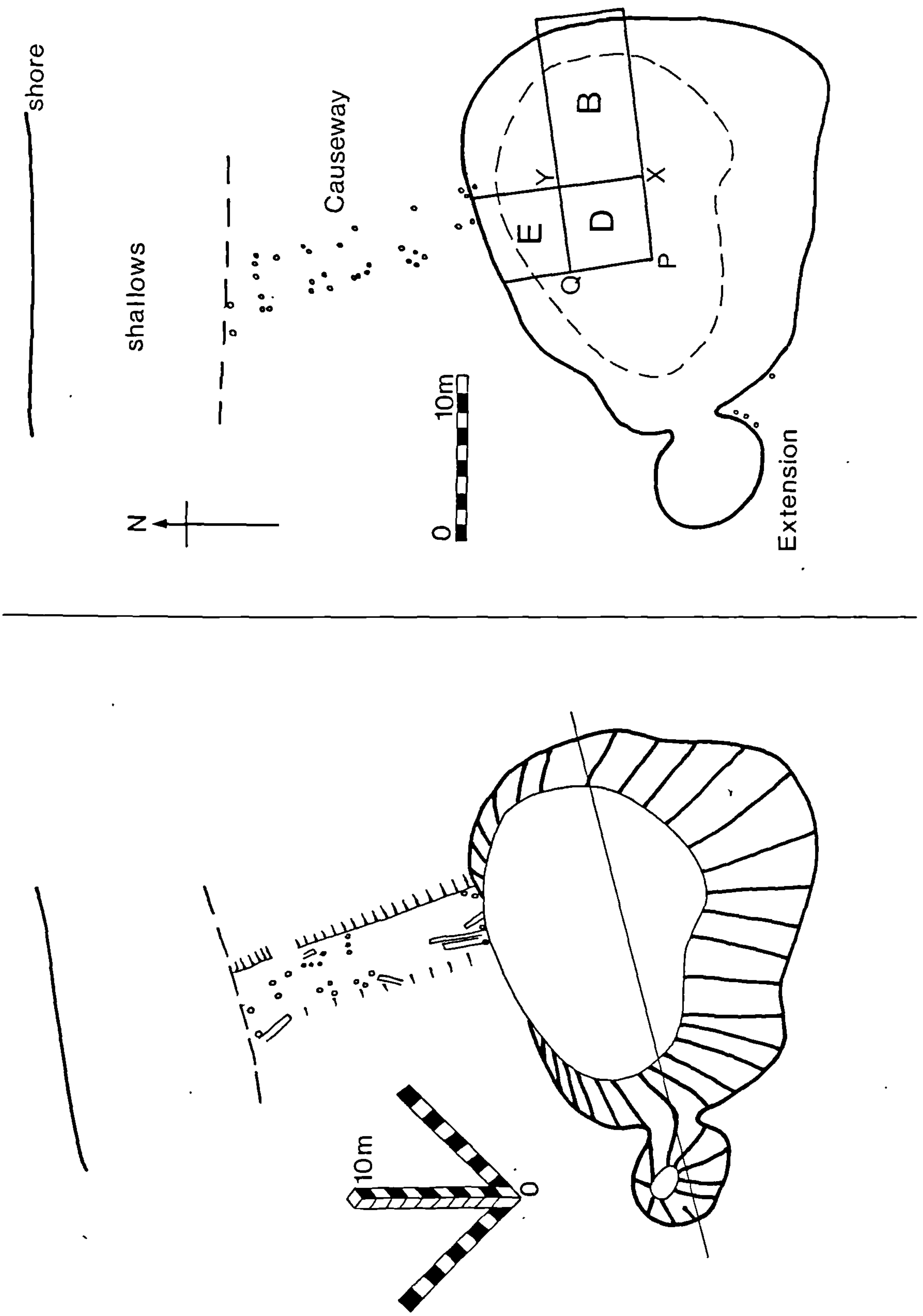


Fig.6 Oakbank; a) axonometric projection (after Morrison, 1985)

b) plan of excavation areas

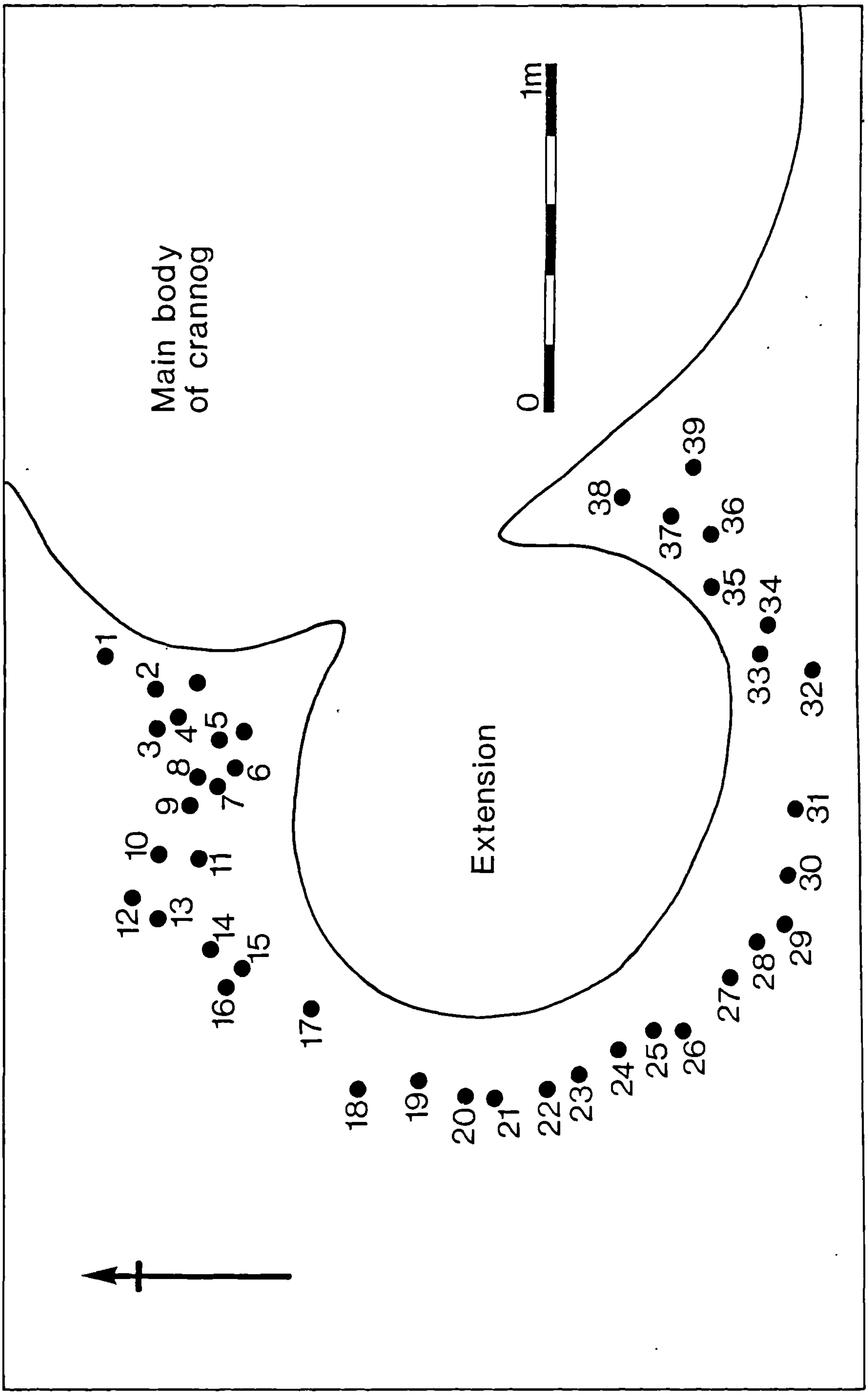


Fig.7 Oakbank; the Extension piles

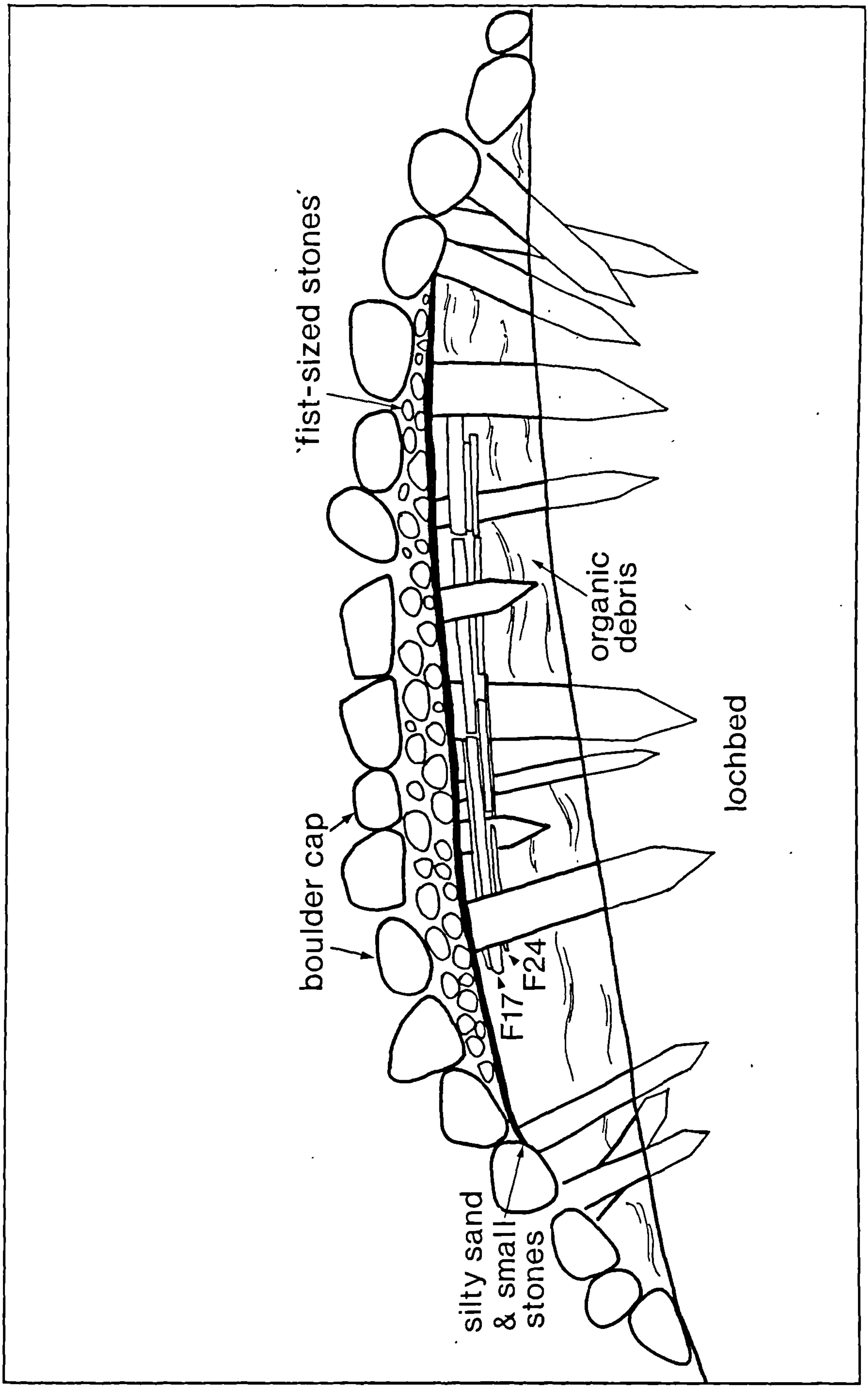


Fig.8 Oakbank; schematic reconstruction of stratigraphy

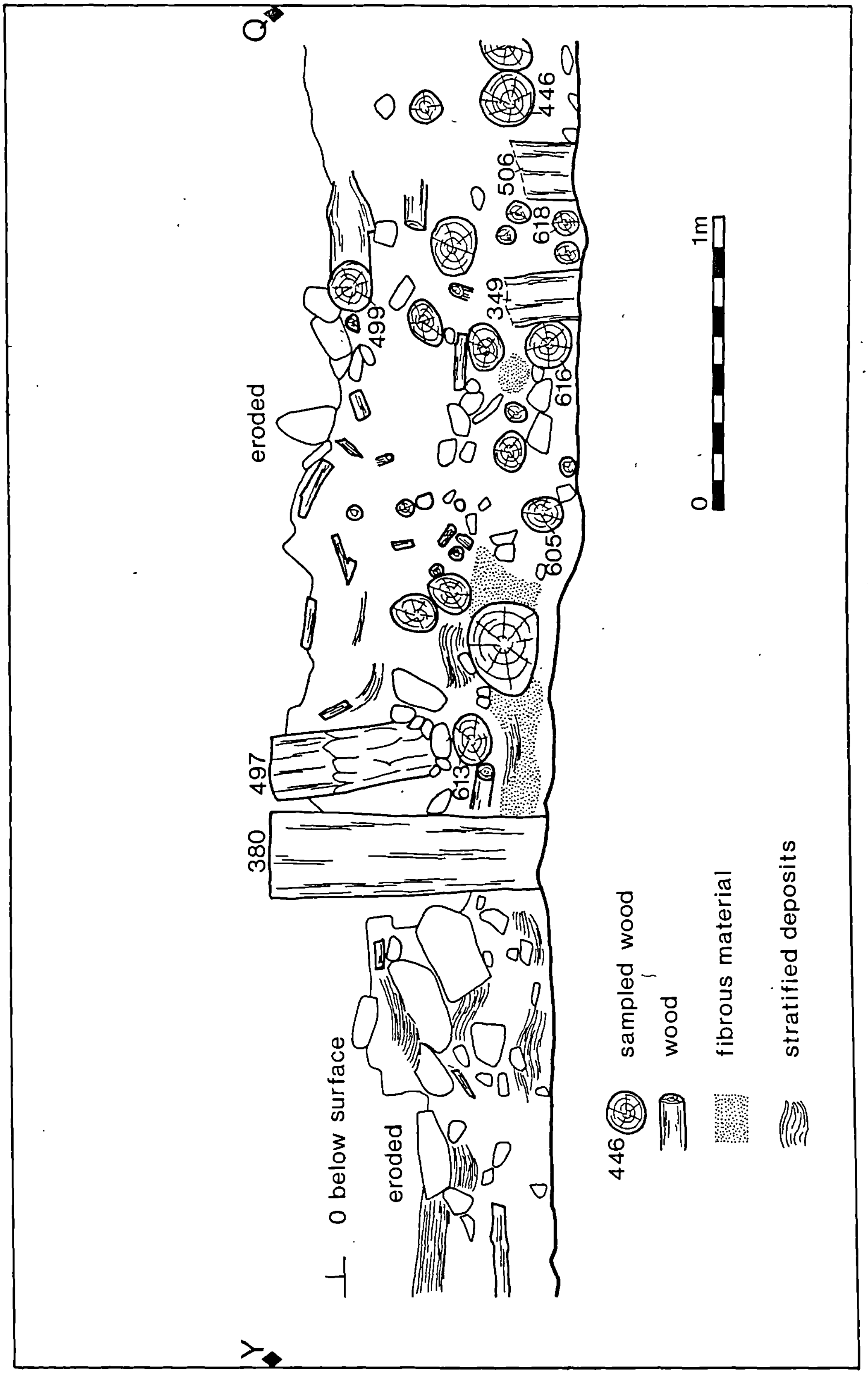


Fig.9 Oakbank; Section YQ

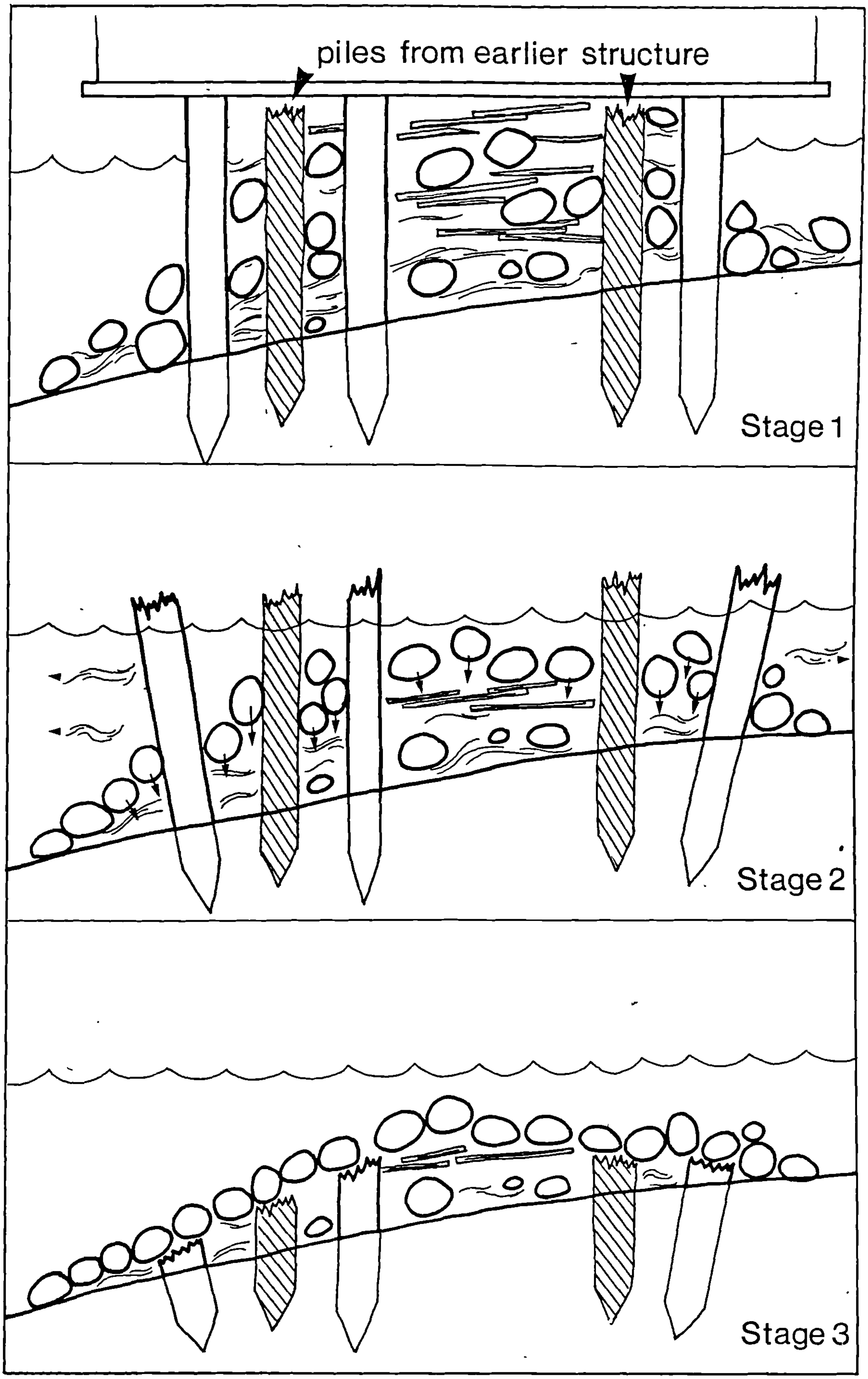
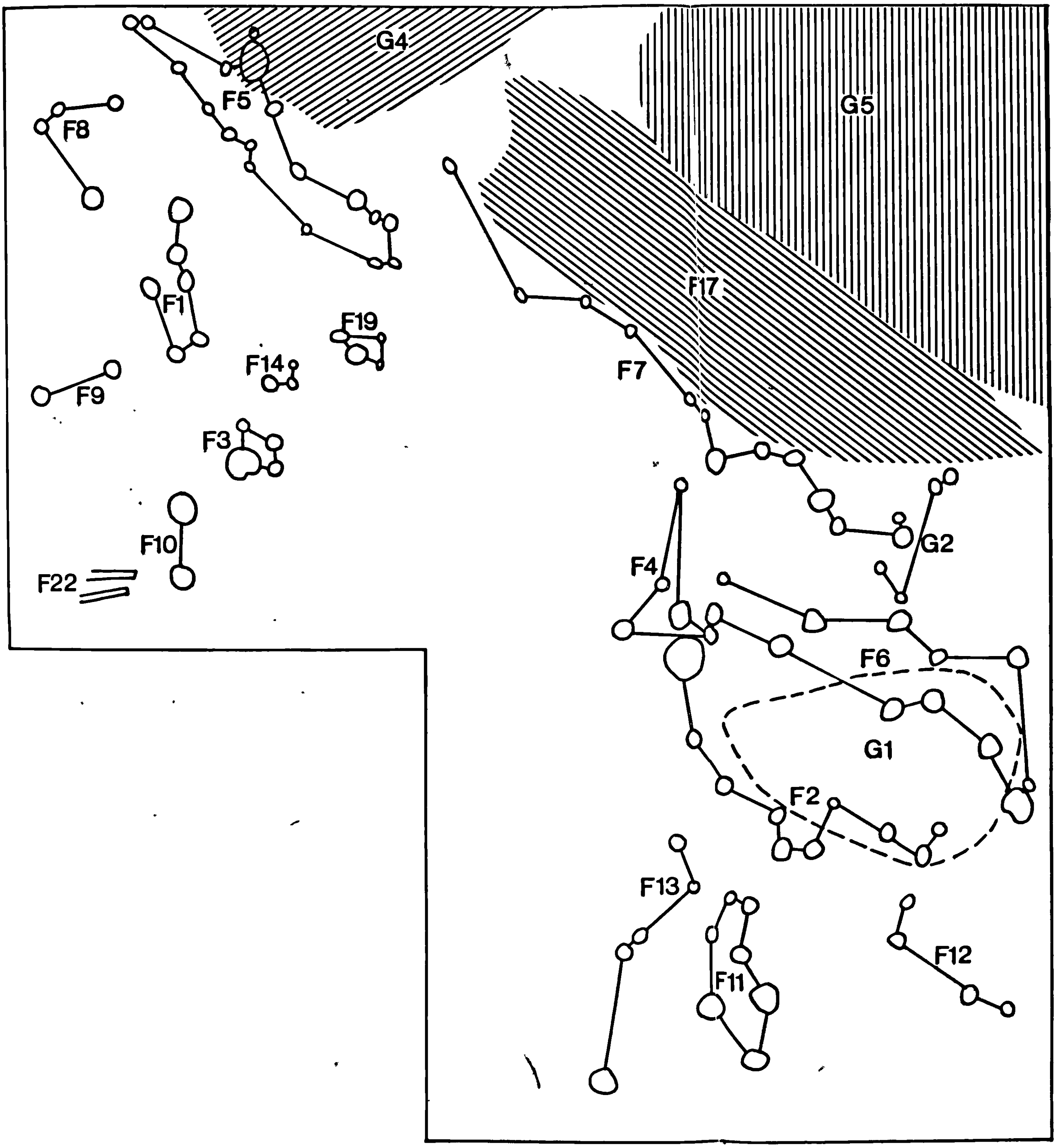


Fig.10 Oakbank; the process of conflation in a crannog


G4
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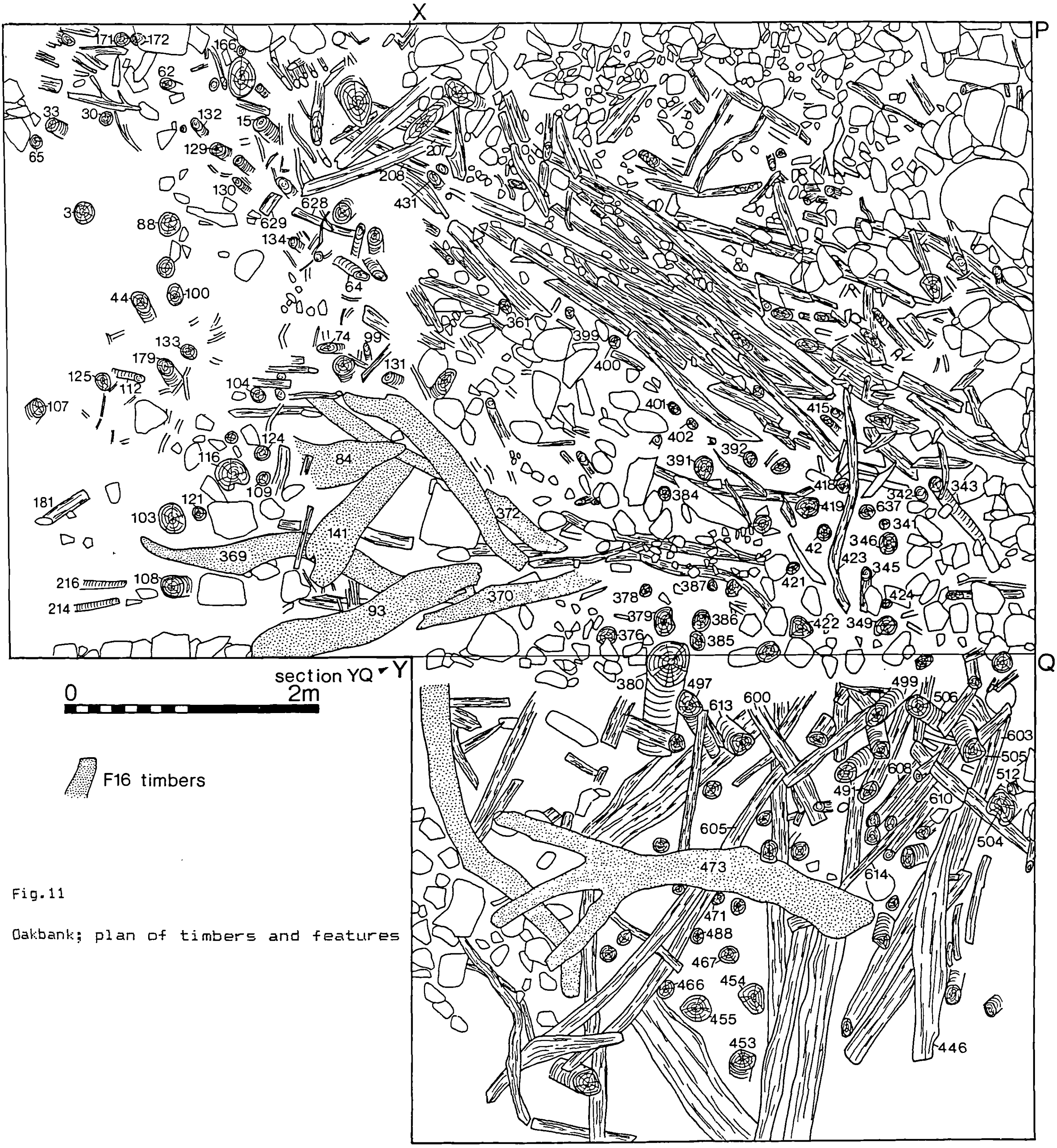
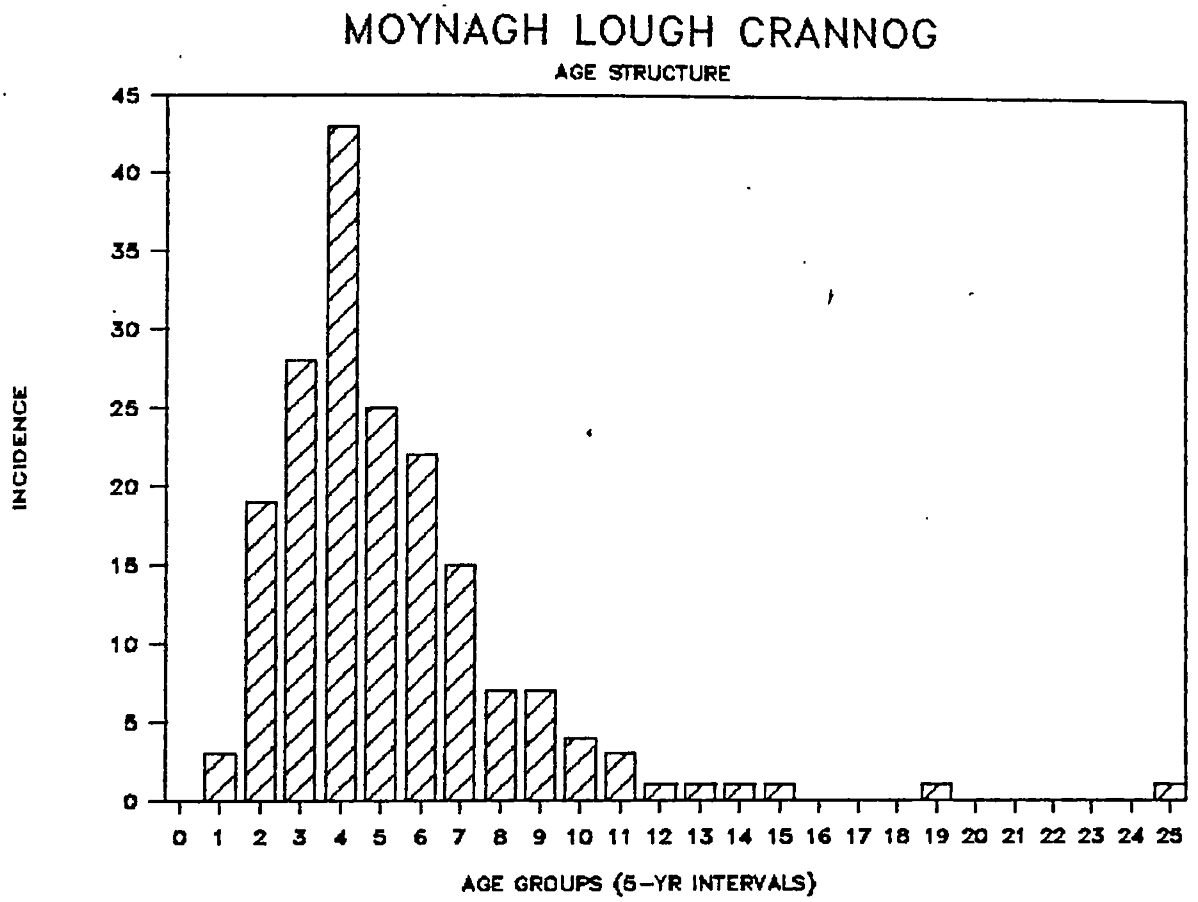


Fig.11

Oakbank; plan of timbers and features



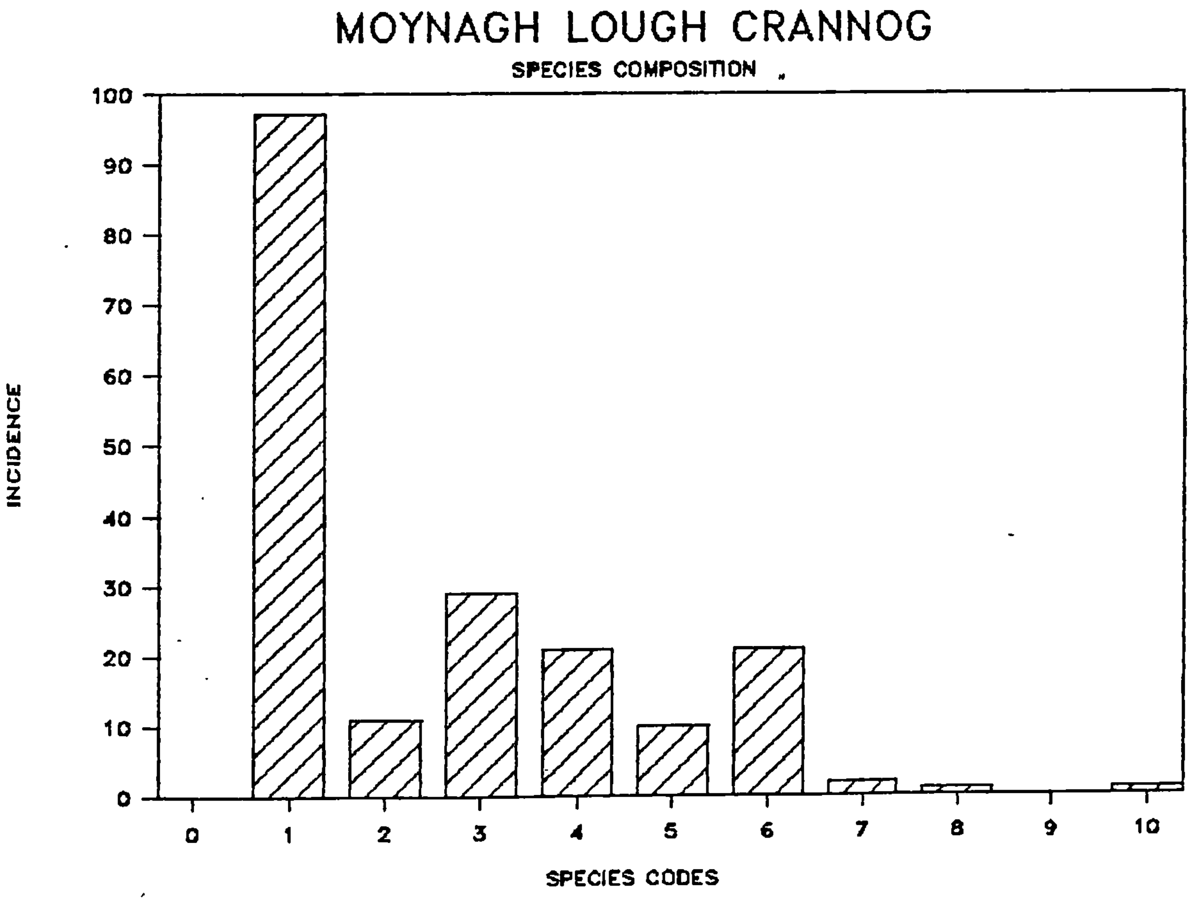
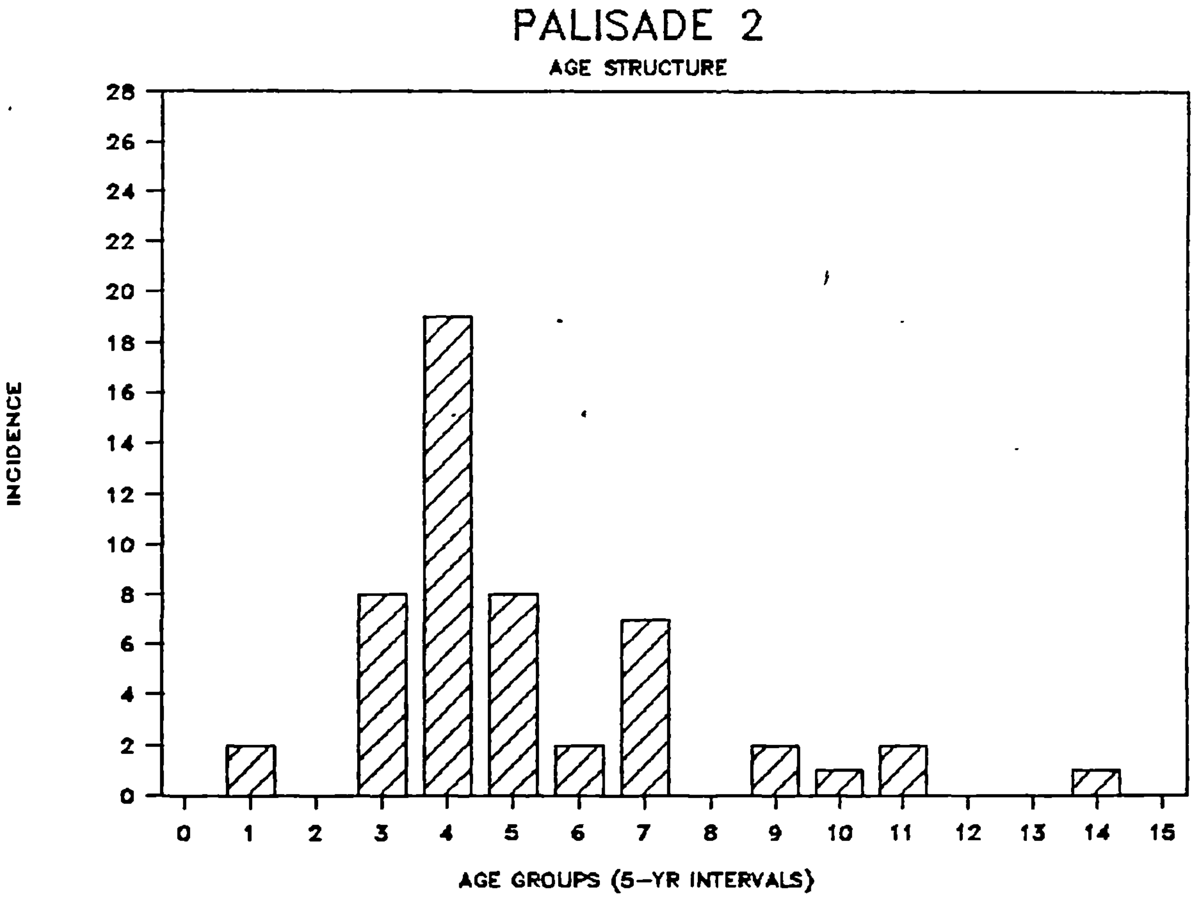


Fig.12 Moynagh Lough; age structure and species composition



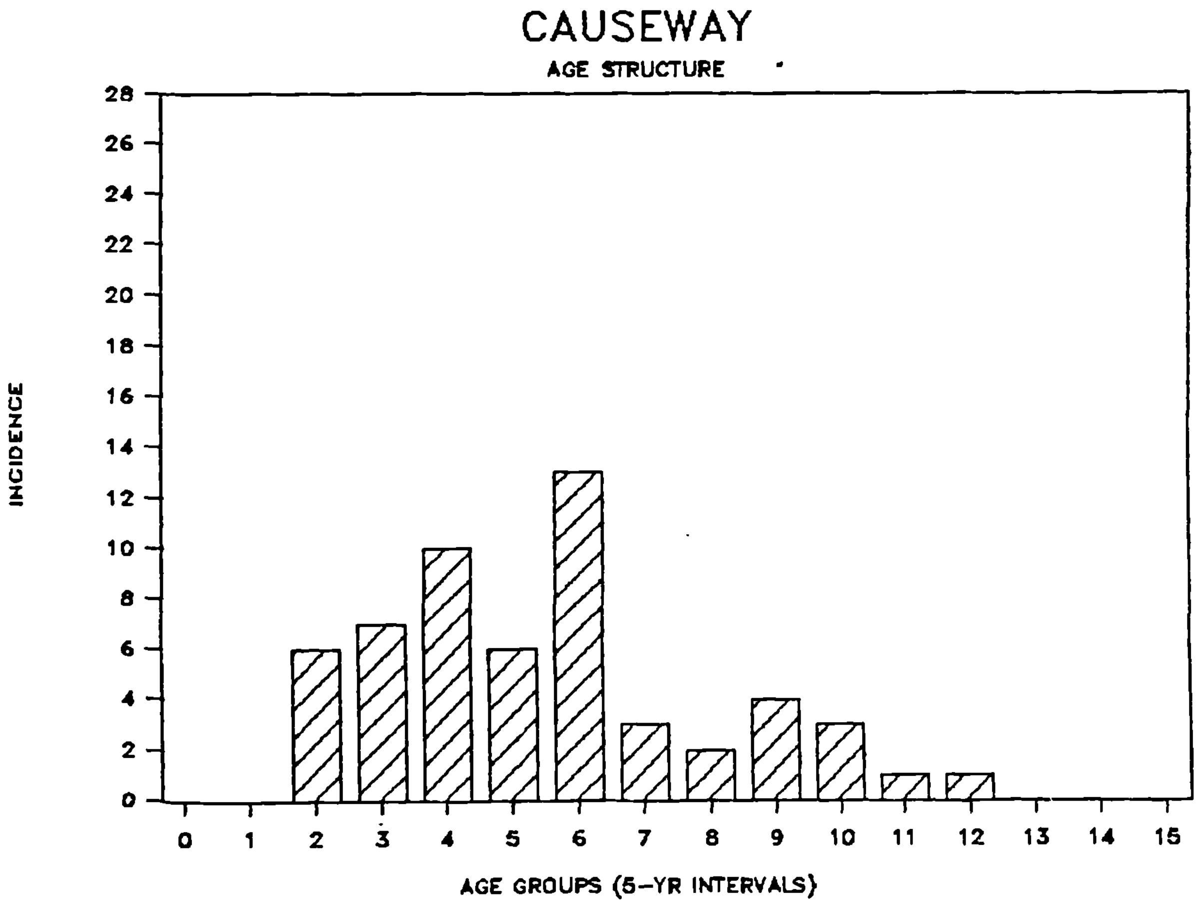


Fig.13 Moynagh Lough; age structure of Palisade 2 and Causeway

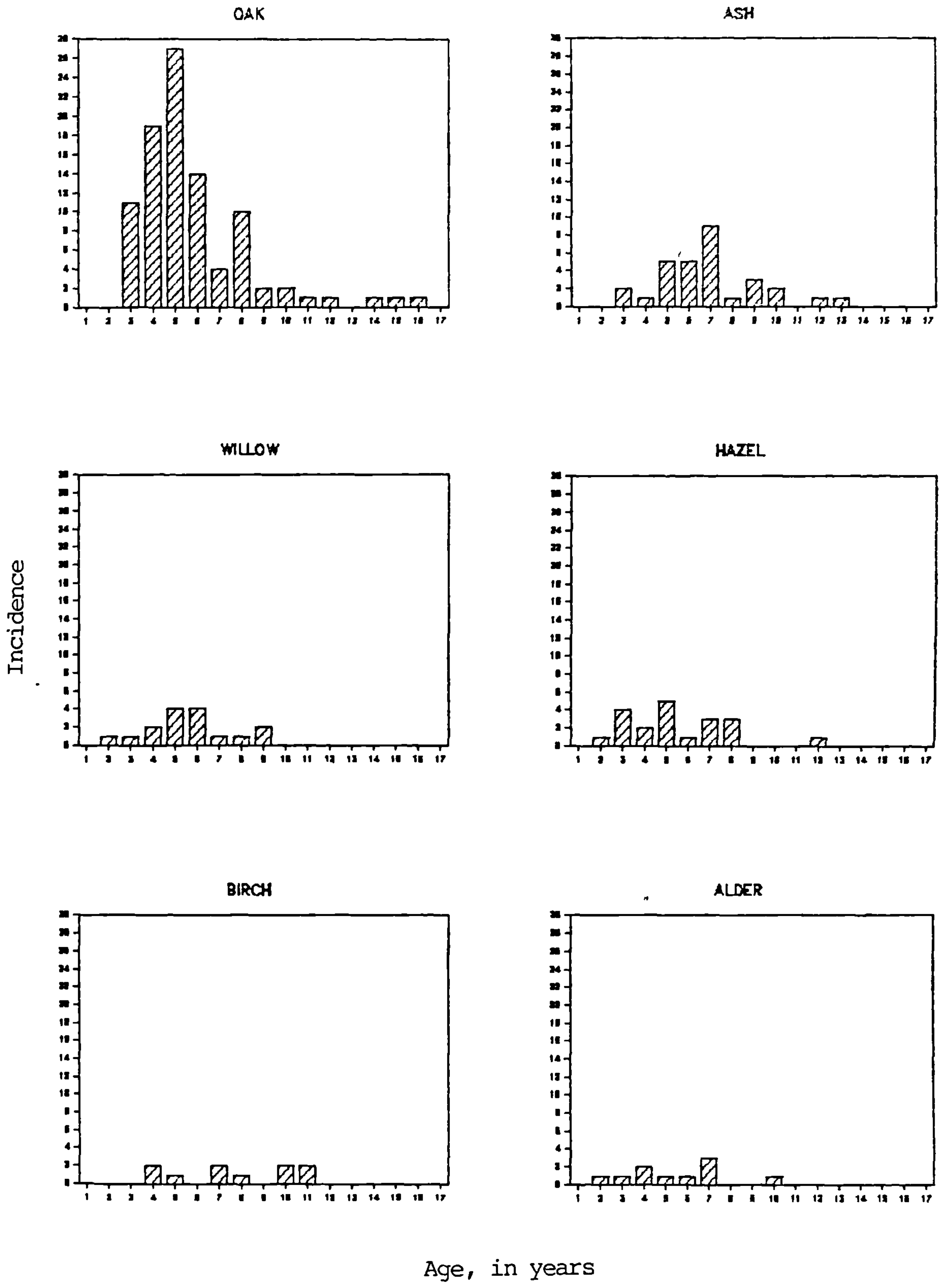


Fig.14 Moynagh Lough; age structure of each species

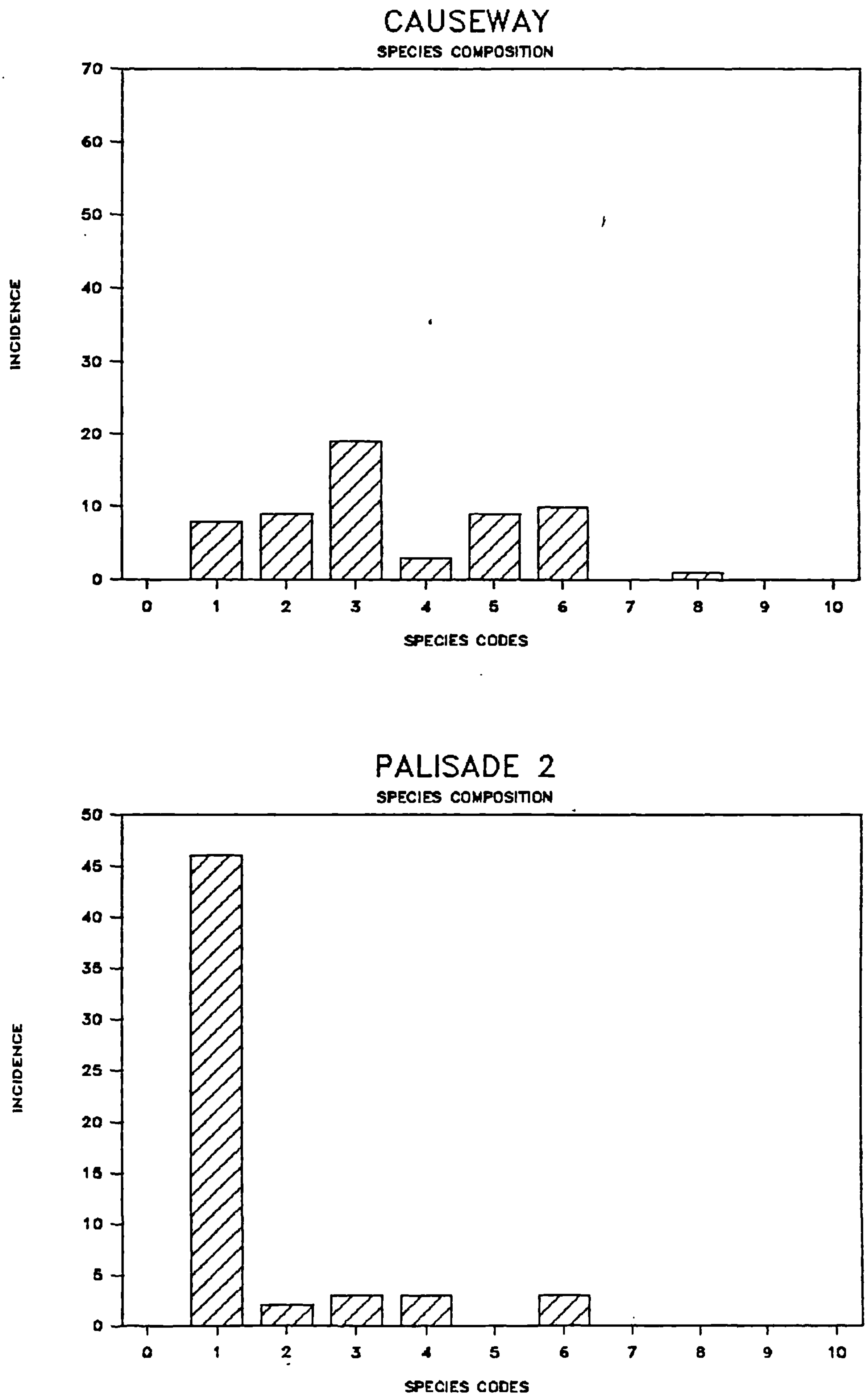
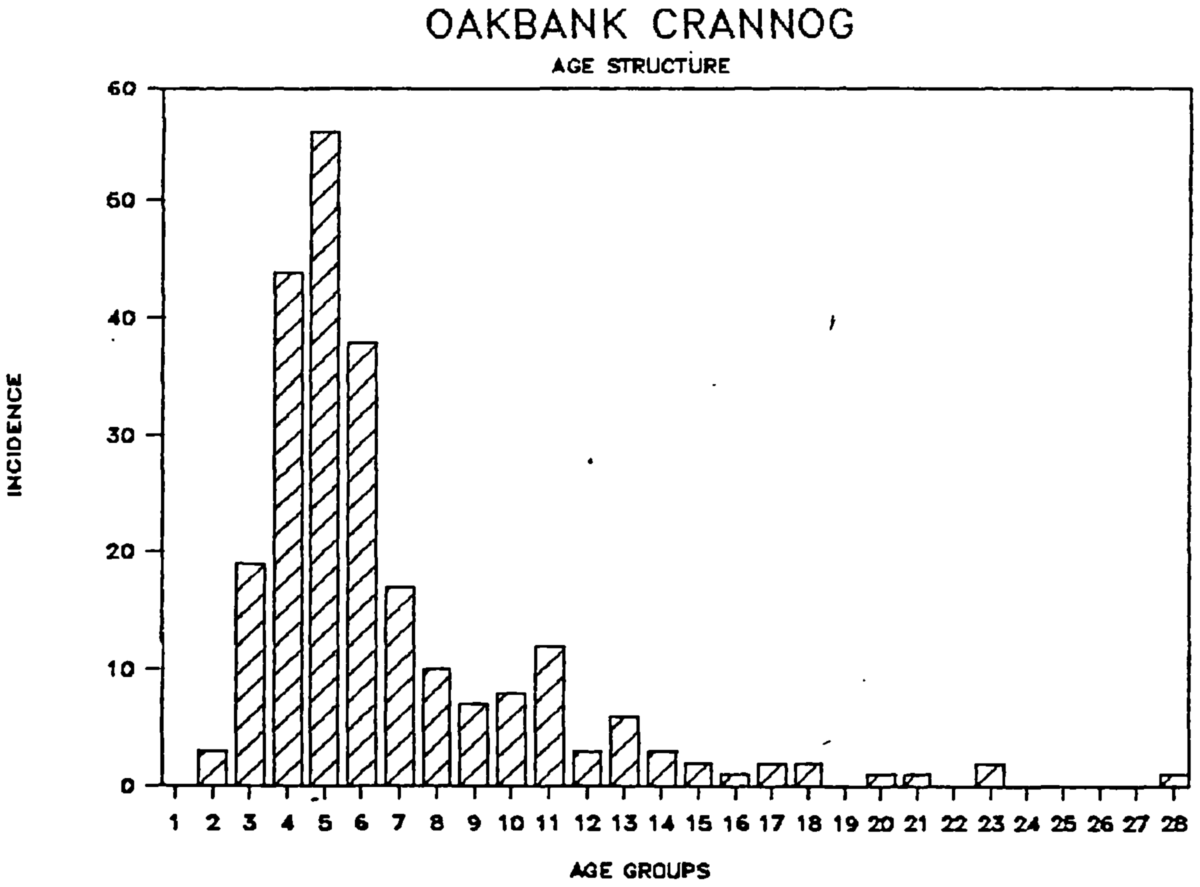


Fig.15. Moynagh Lough; species composition of Palisade 2 and Causeway



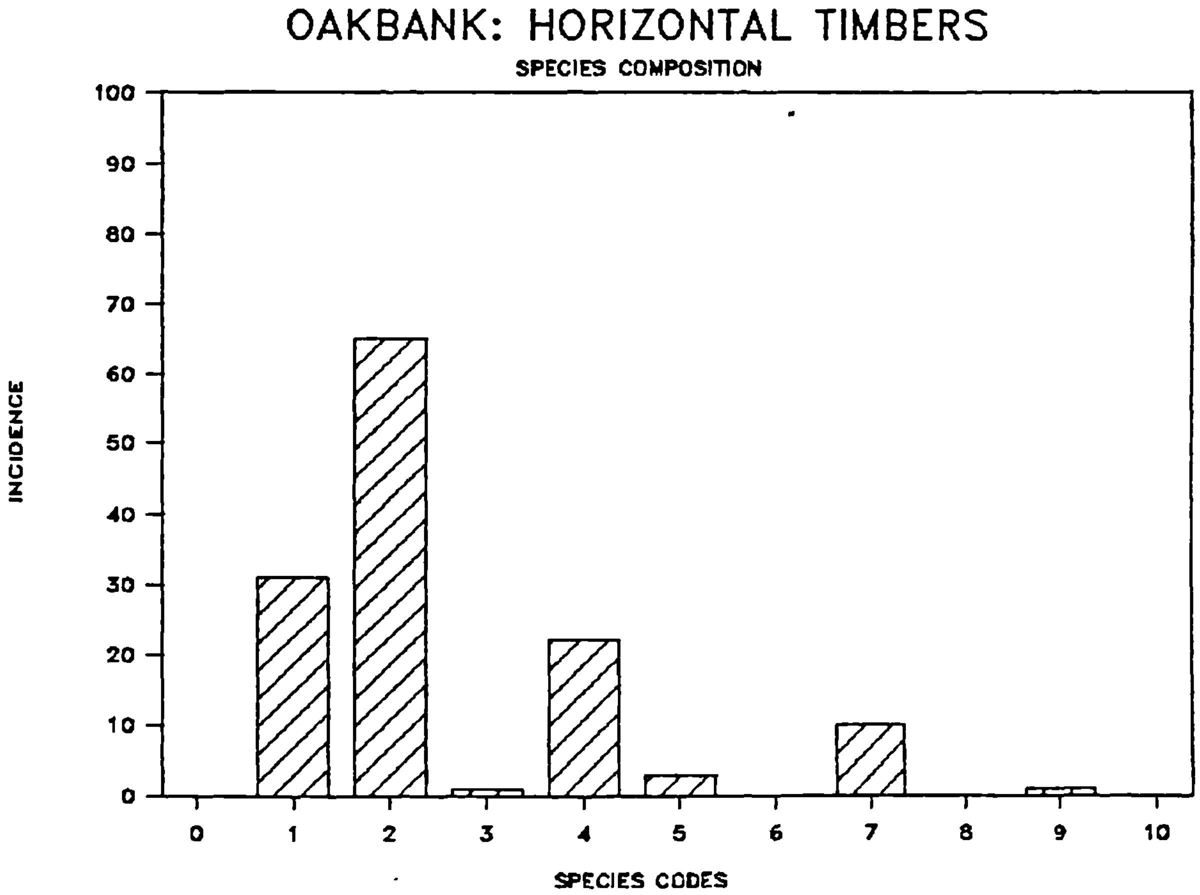


Fig.16 Oakbank; age structure and species composition

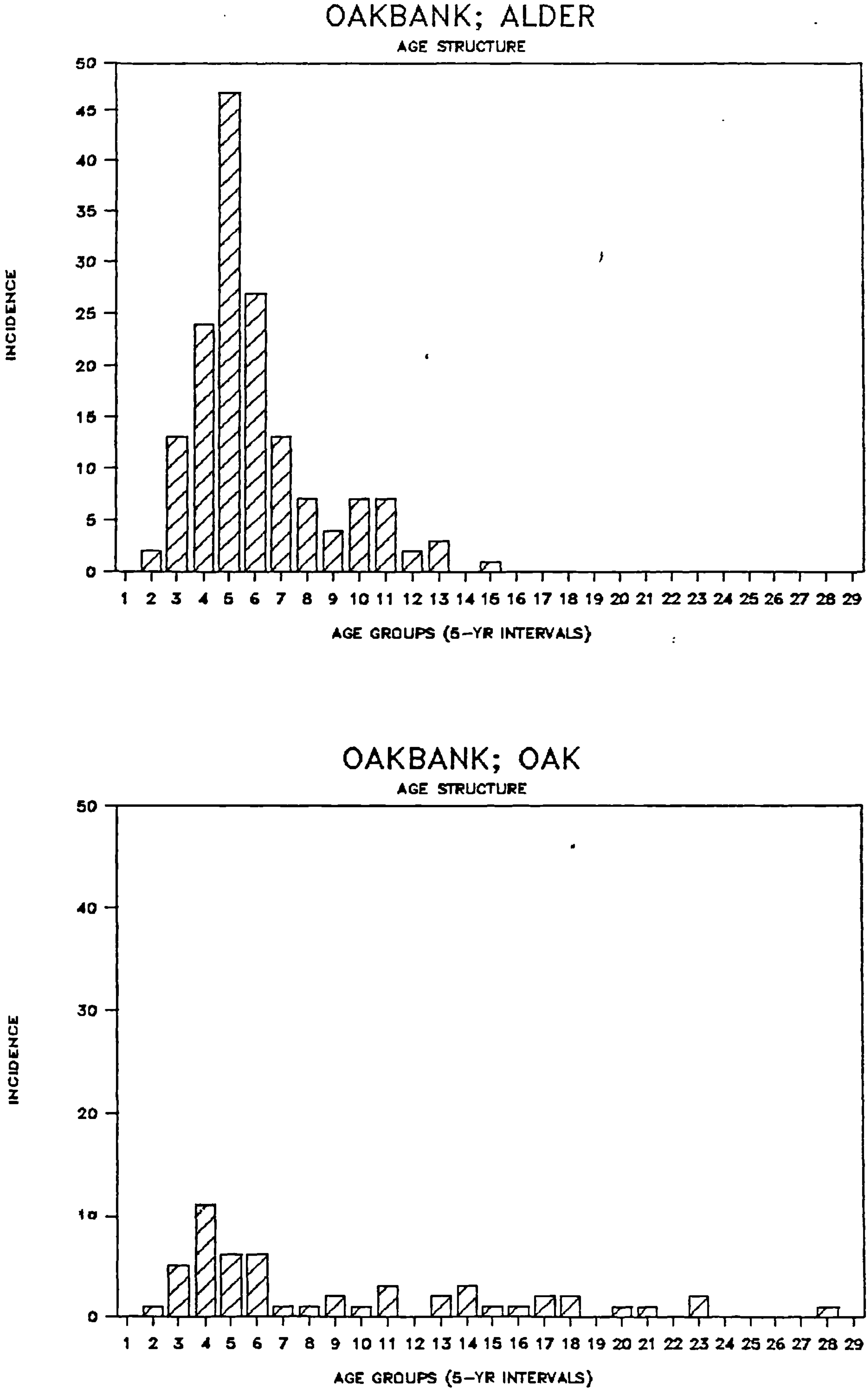


Fig.17 Oakbank; age structure of alder and oak

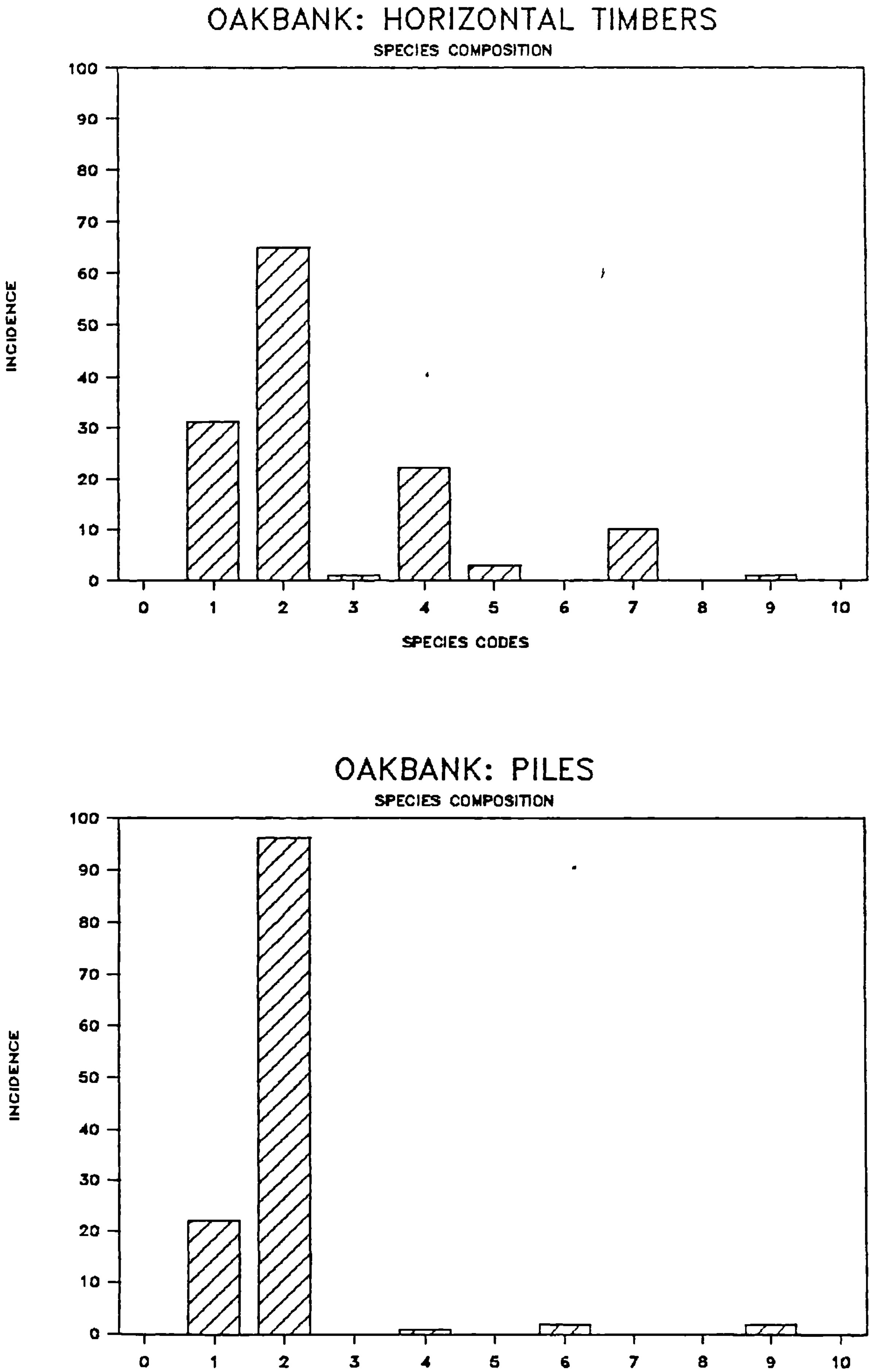
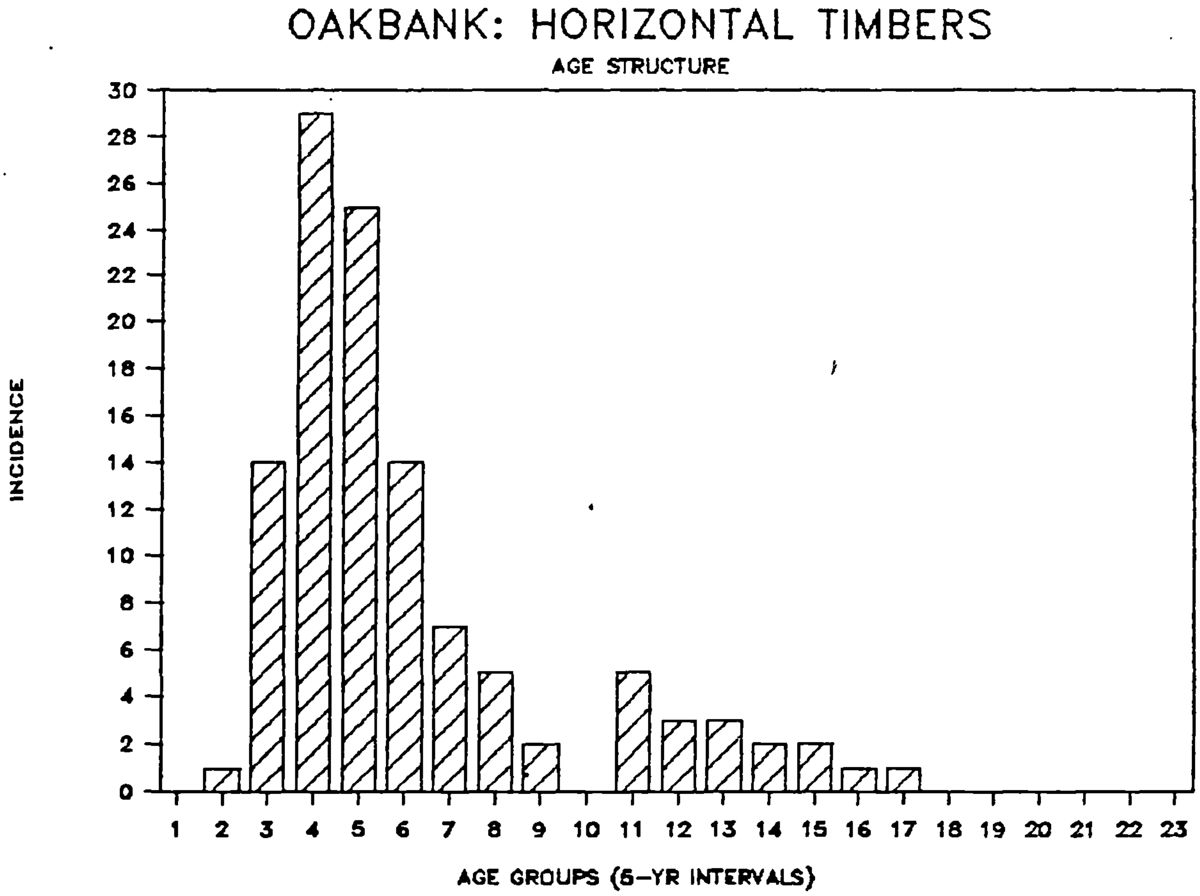
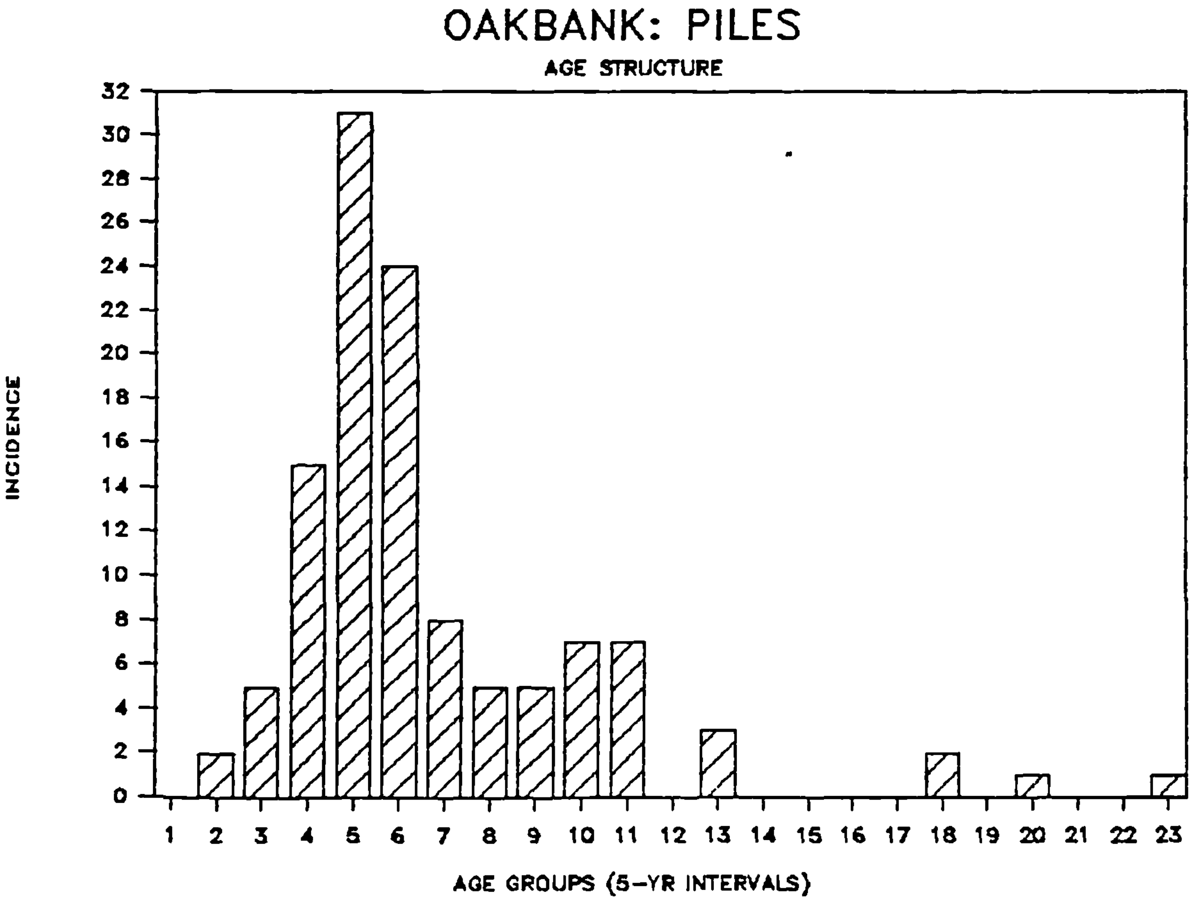


Fig.18 Oakbank; species composition of Piles and Horizontal timbers



OAKBANK: HORIZONTAL TIMBERS

AGE STRUCTURE



OAKBANK: PILES

AGE STRUCTURE

Fig.19 Oakbank; age structure of Piles and Horizontal timbers

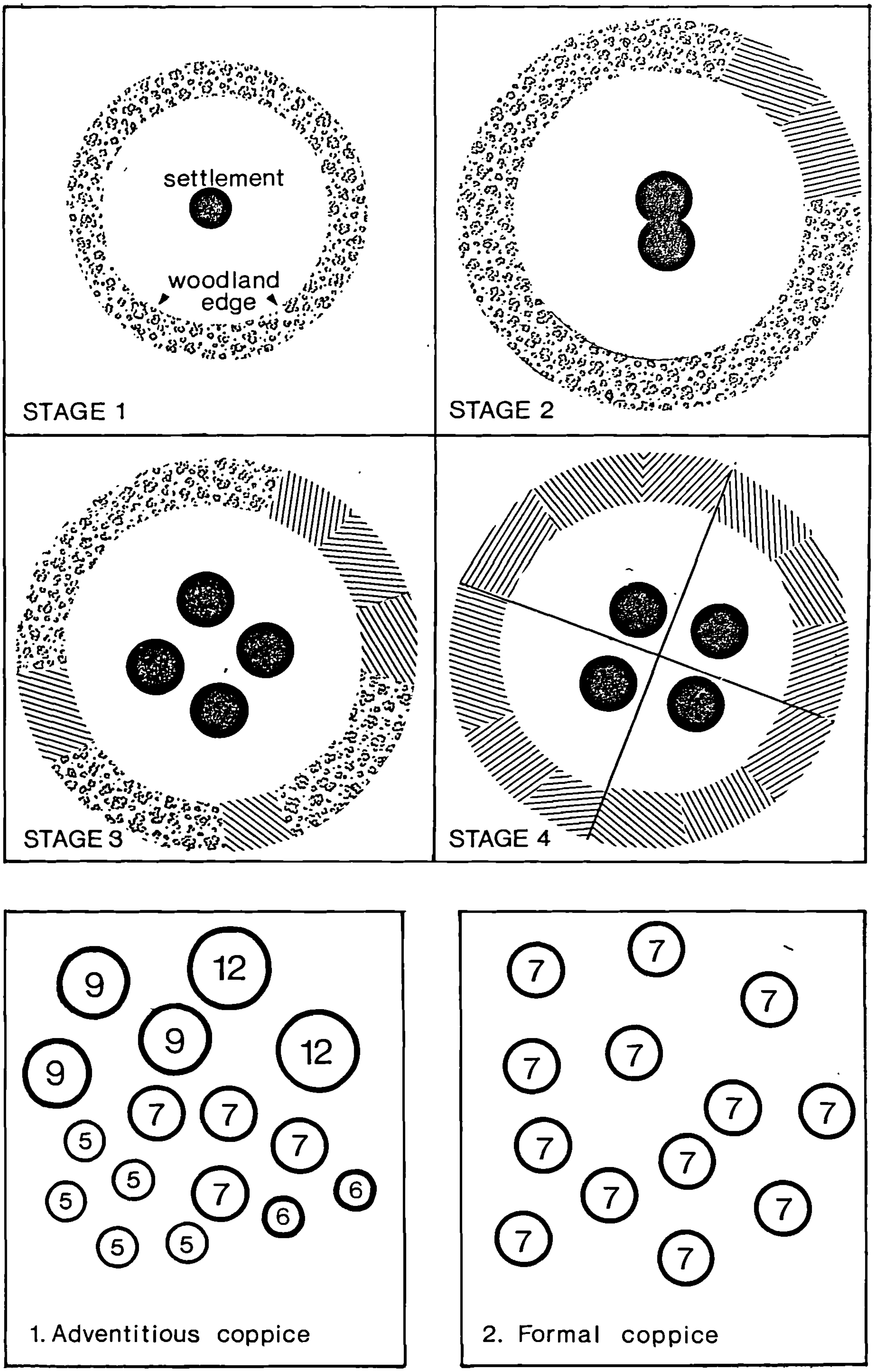


Fig.20

a) stages in the transition from unmodified woodland to formally coppiced woodland

b) age structure of i) adventitious coppice and ii) formal coppice

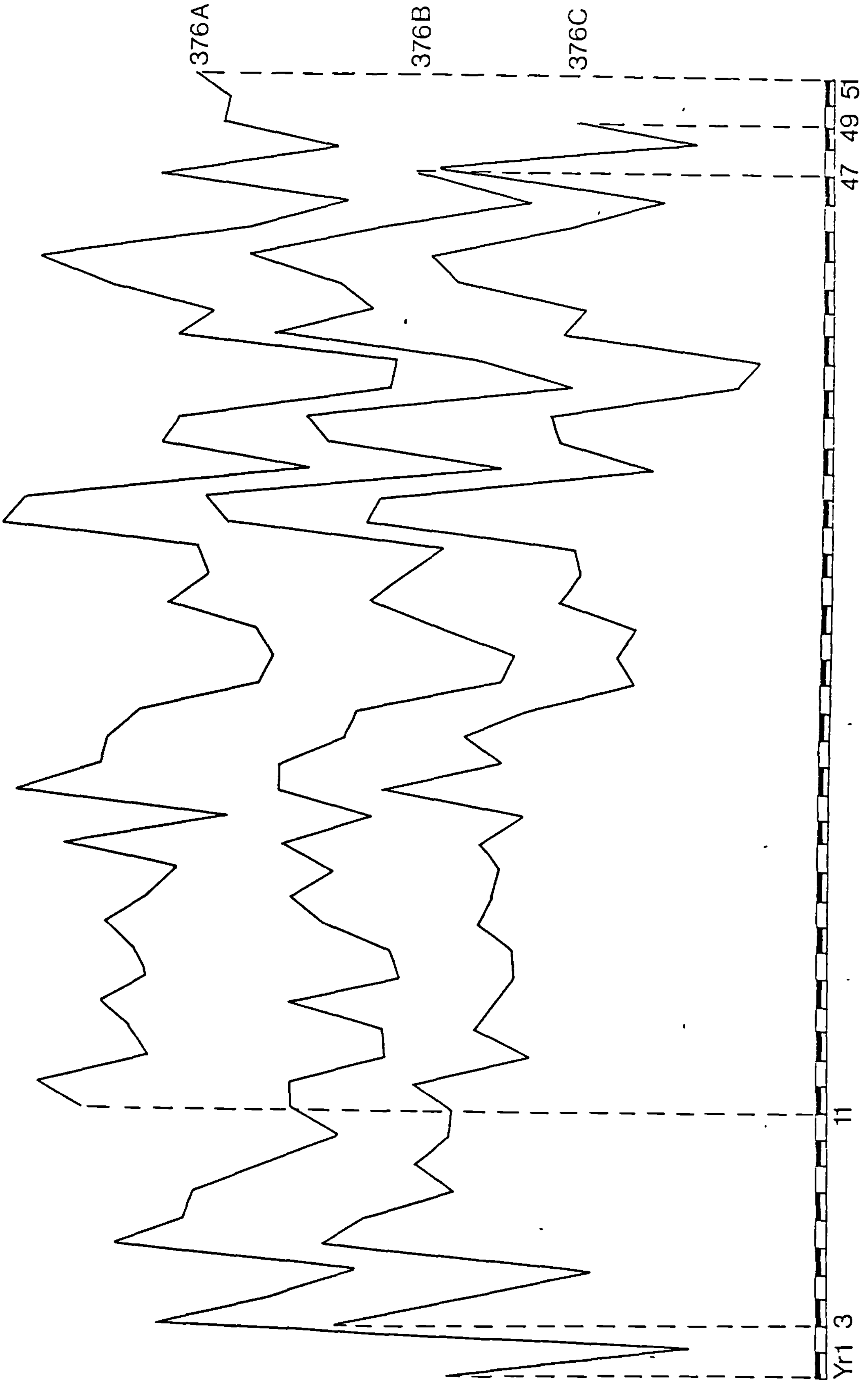


Fig.21

Alder; staggered beginnings and ends on ring-sequences along different radii

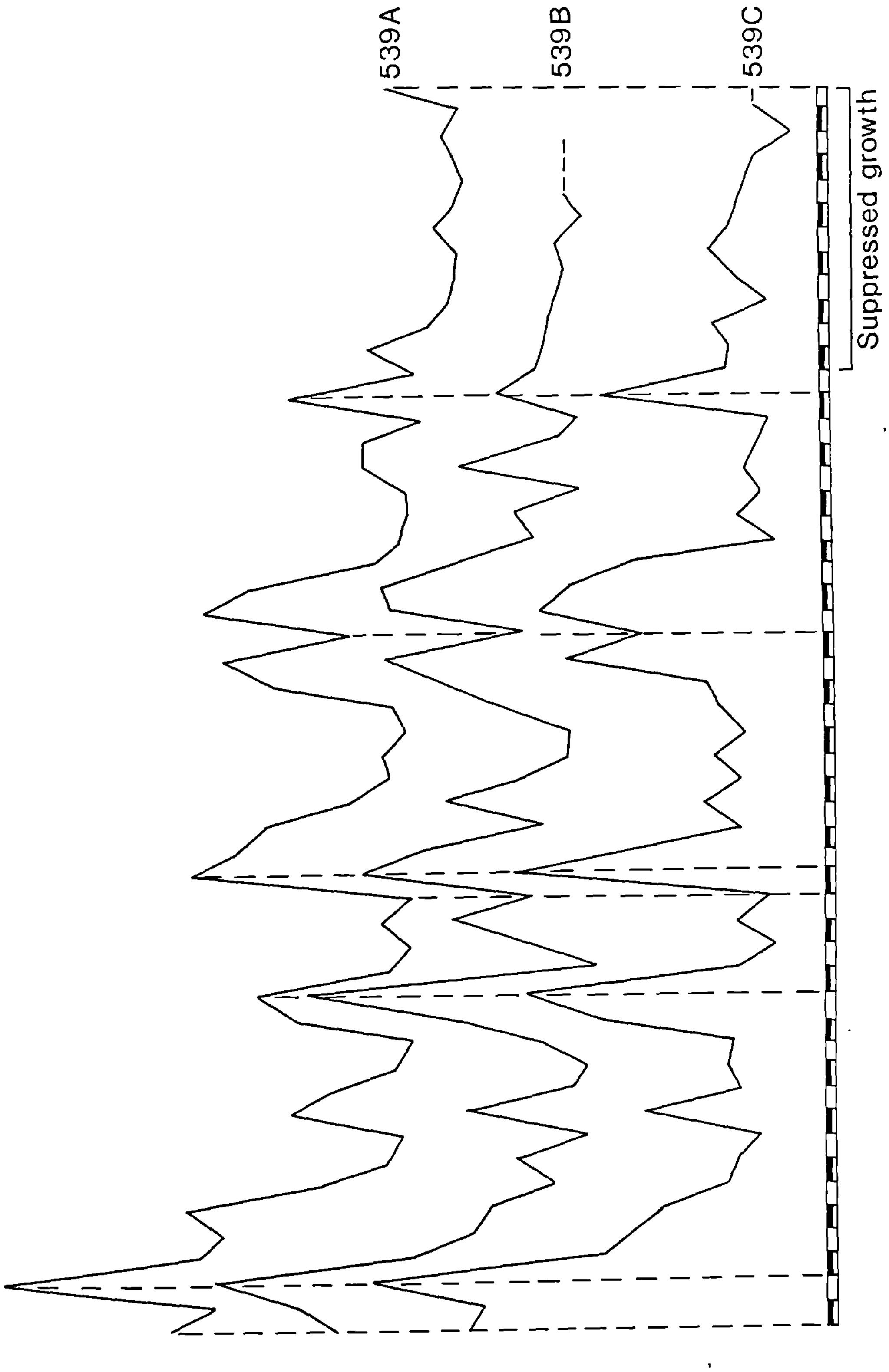


Fig.22 Hazel; suppressed growth

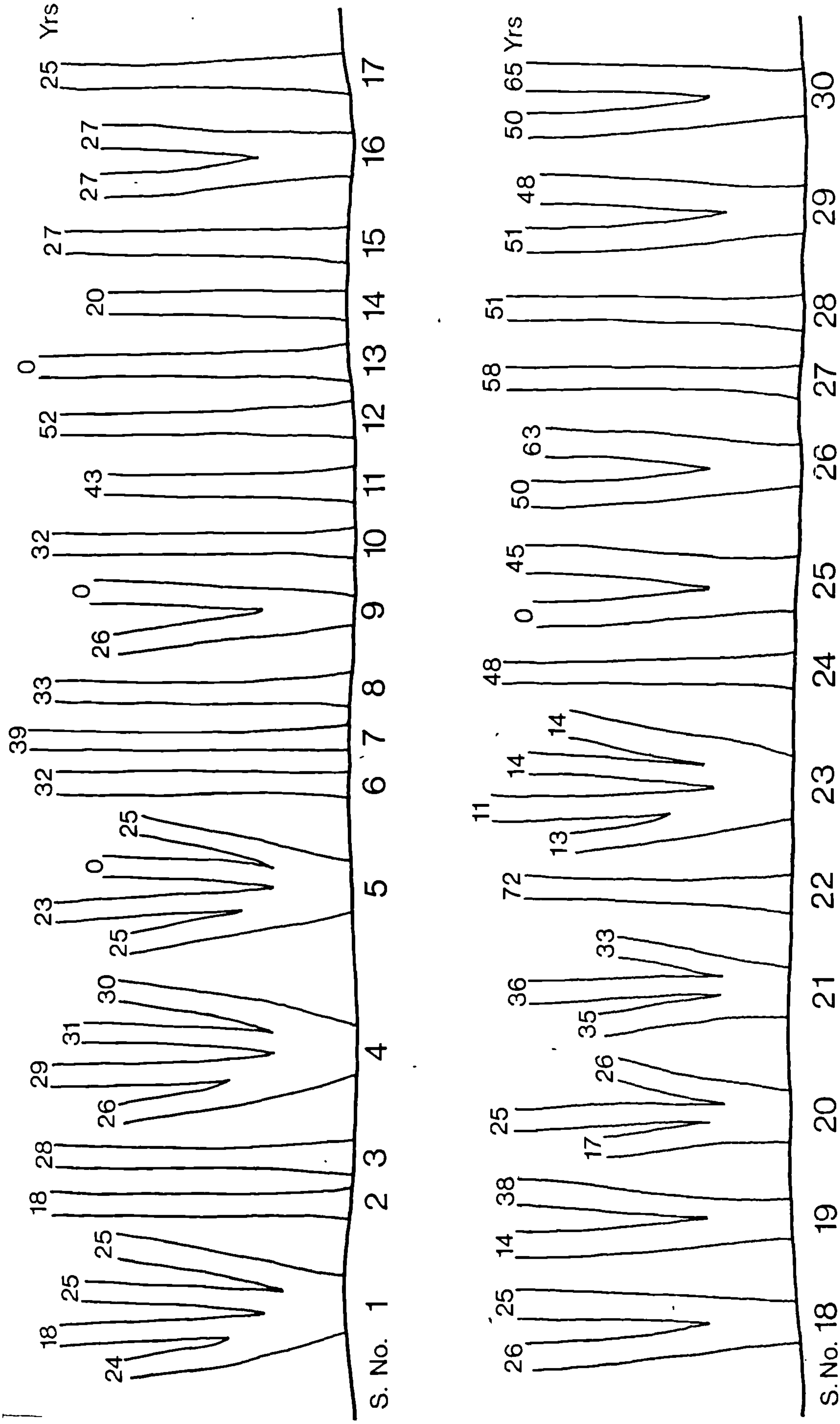


Fig.23 Modern alder; sample numbers and ages

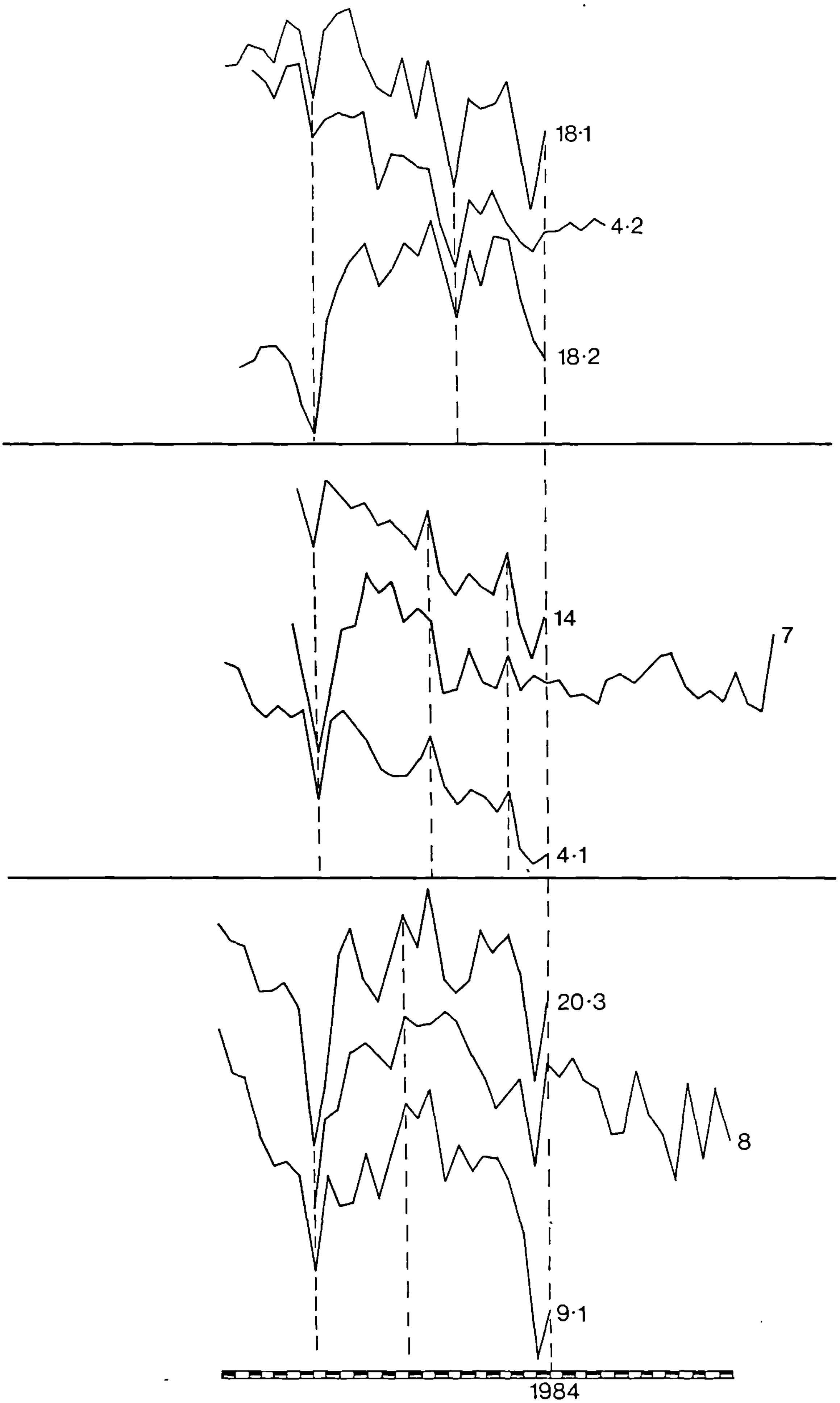


Fig.24 Modern alder; erroneous correlations

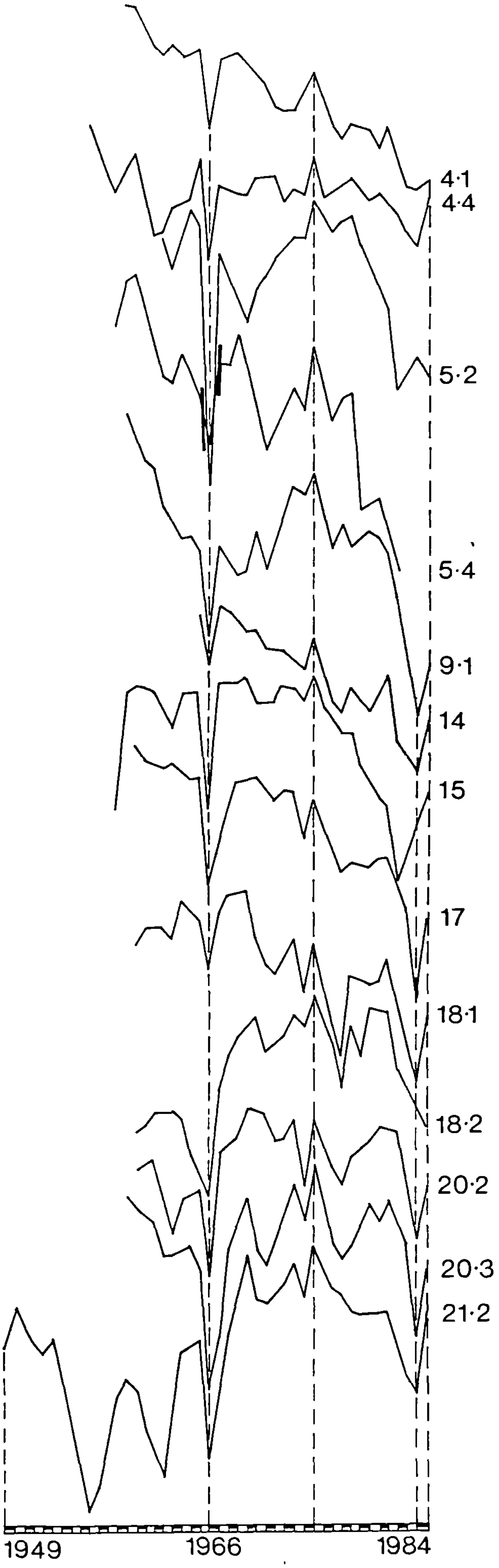


Fig.25 Modern alder; the Target group

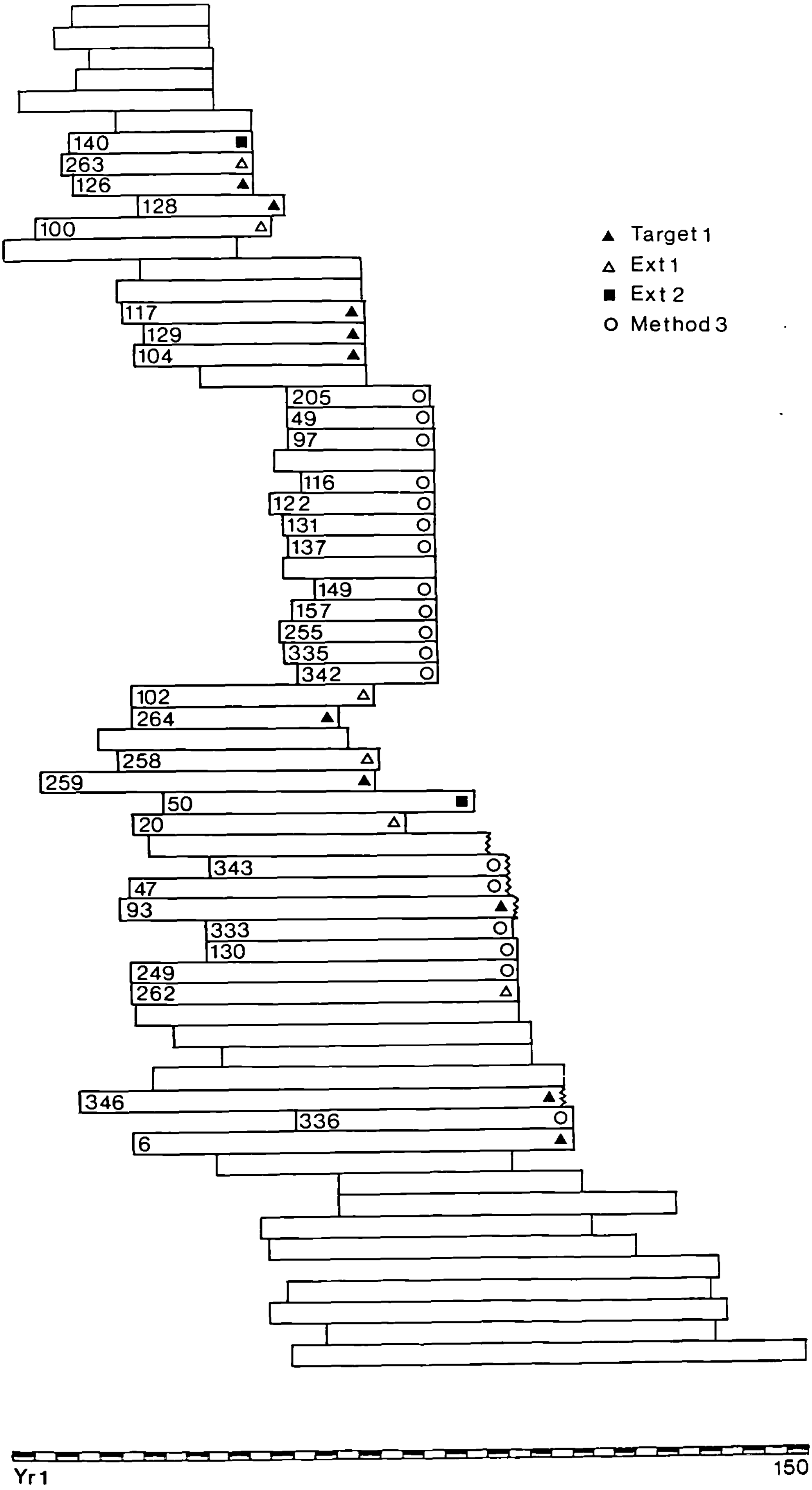


Fig.26 Fiskerton oak; Target 1

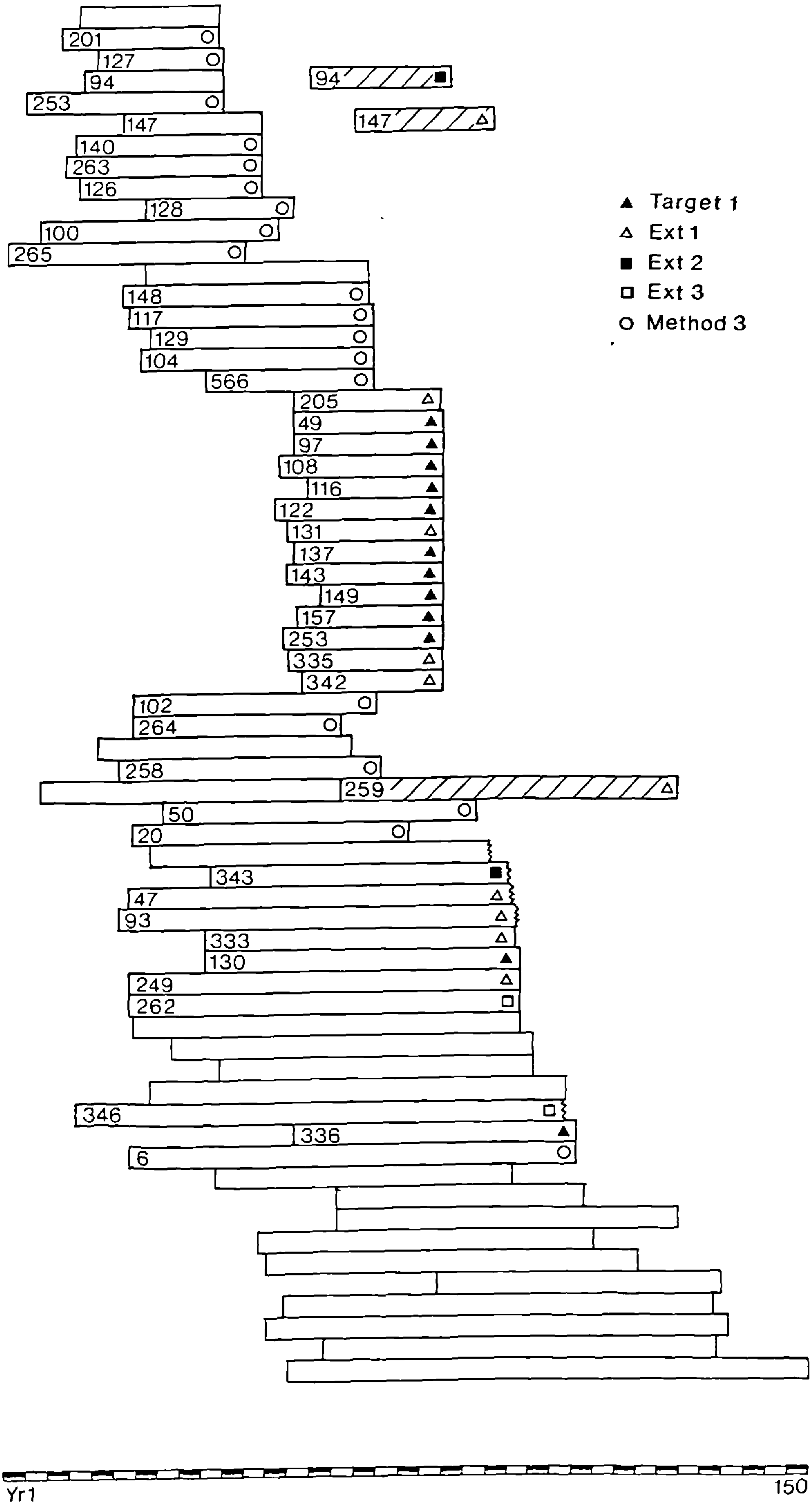


Fig.27 Fiskerton oak; Target 2

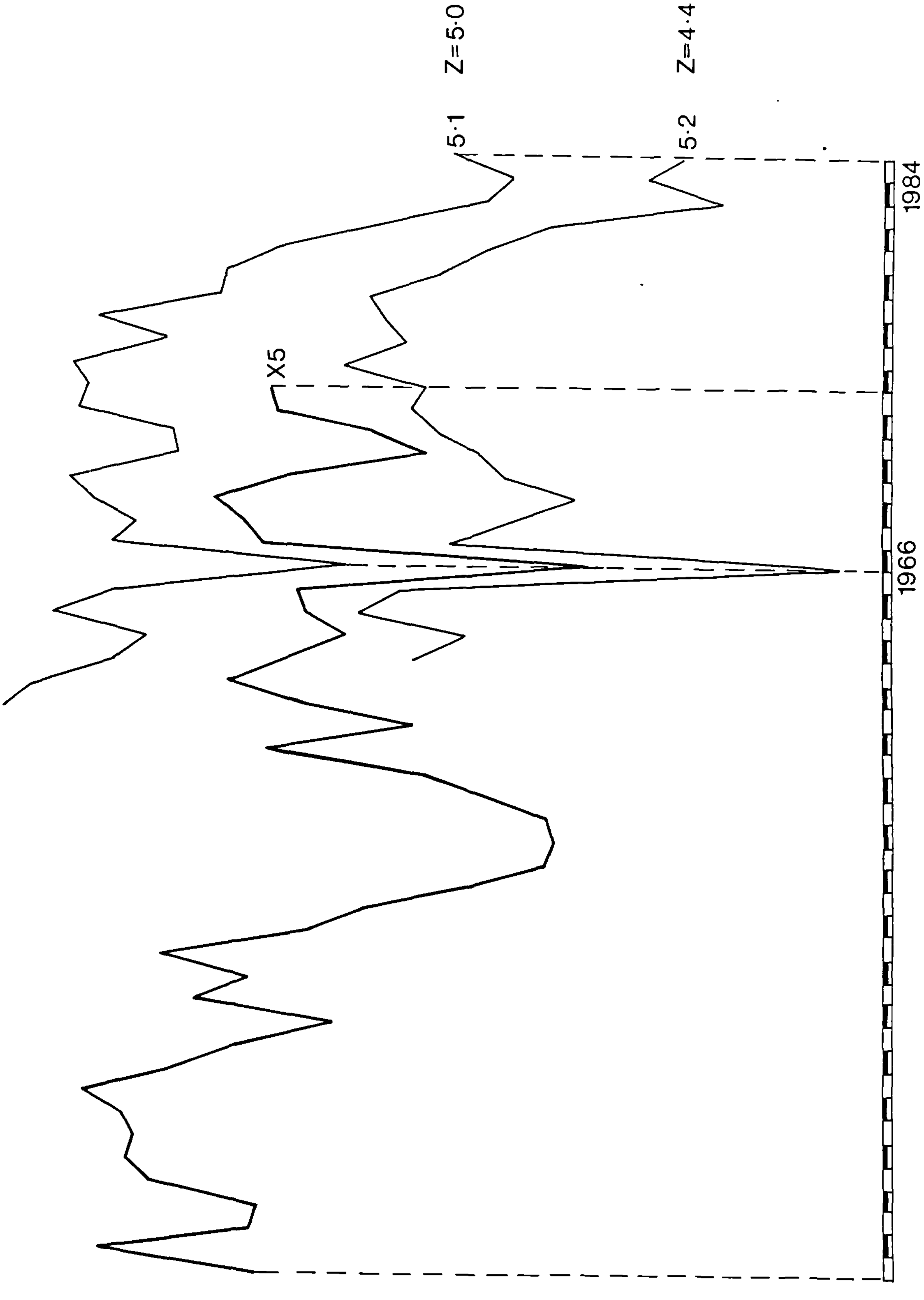
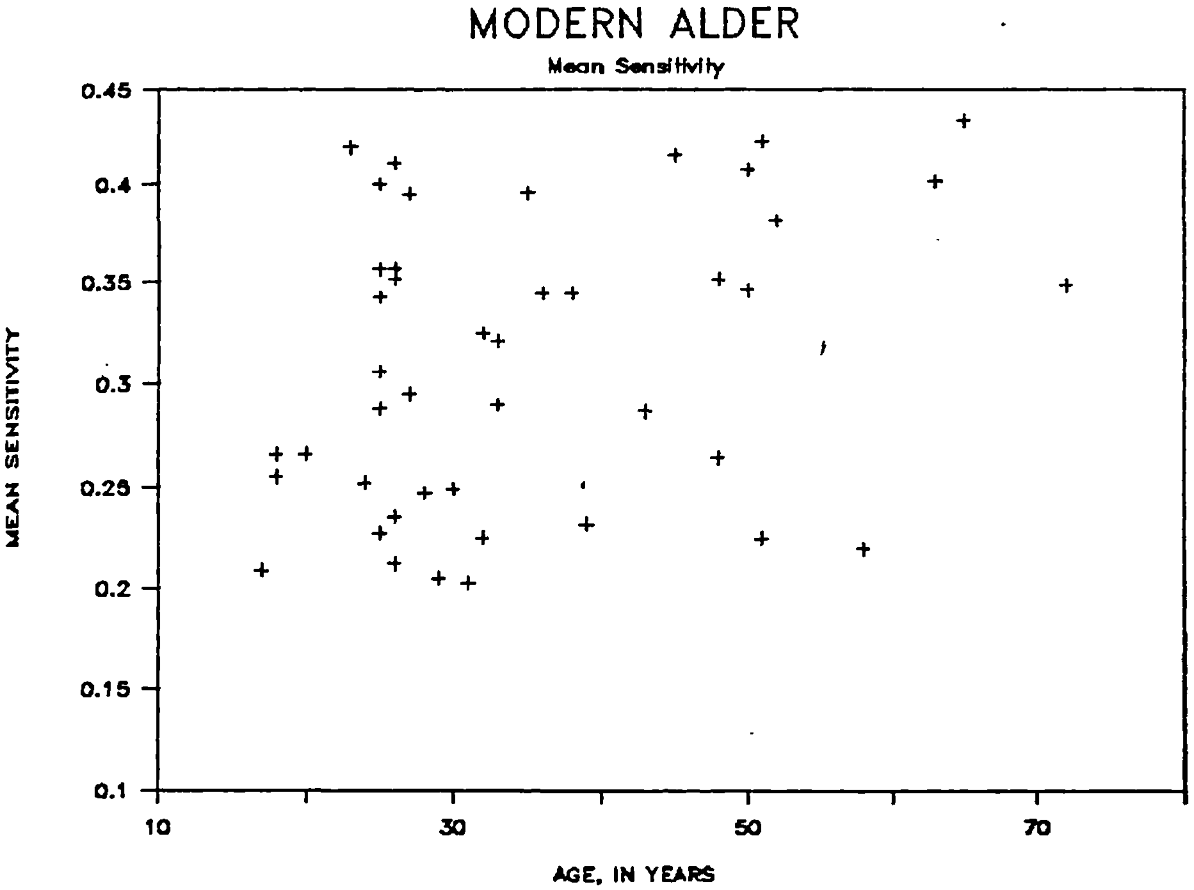


Fig.28 Mismatch between ancient and modern alder



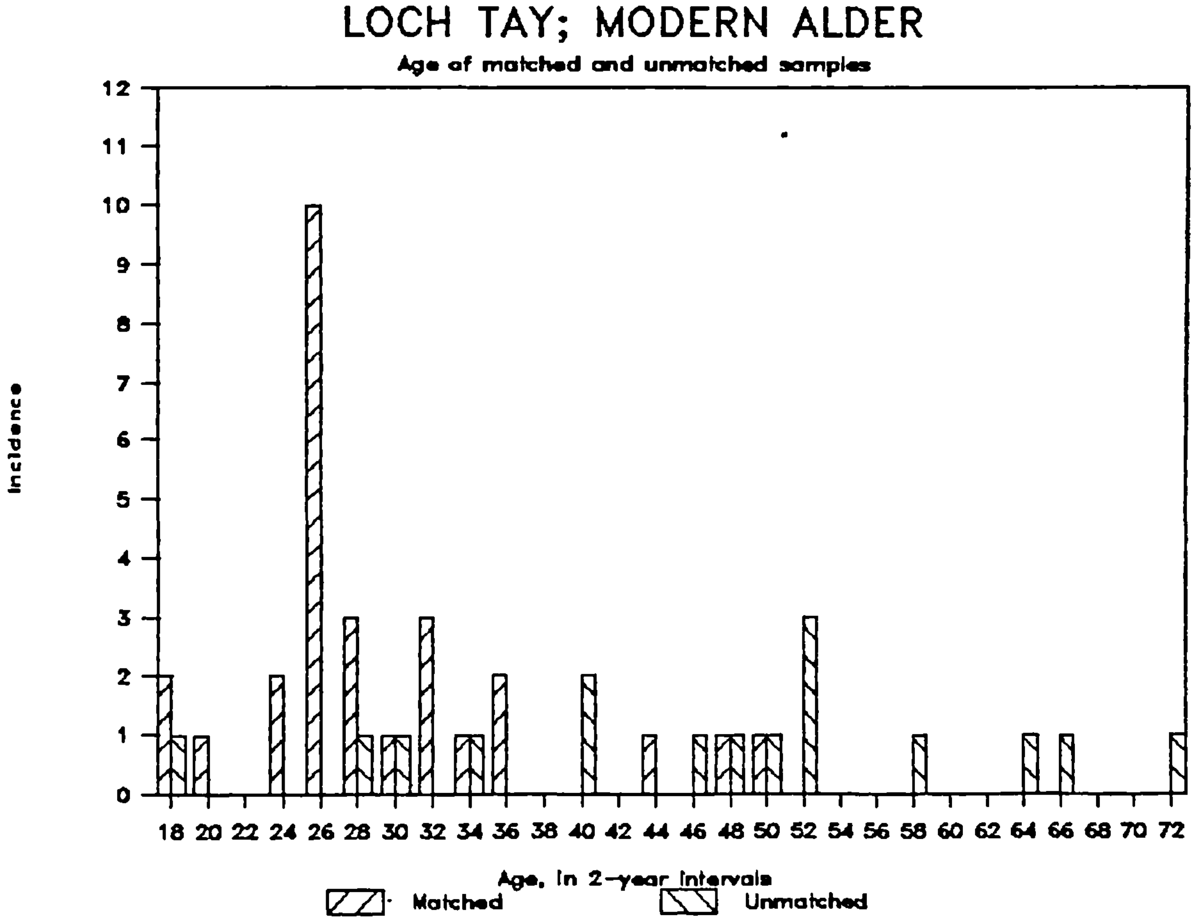


Fig.29 Modern alder; mean sensitivity and age of matched and unmatched samples

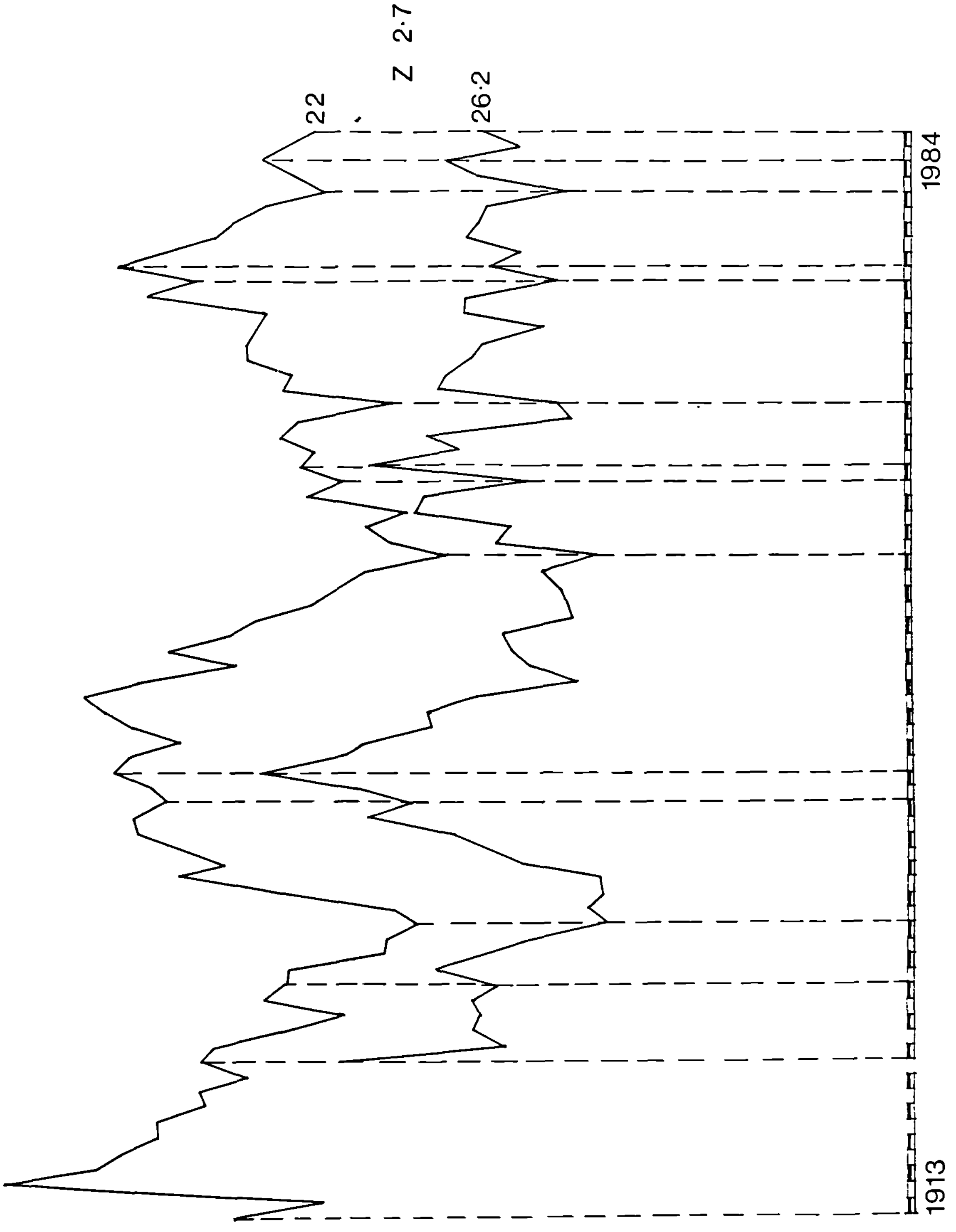


Fig.30 Modern alder; correlation between longer sequences

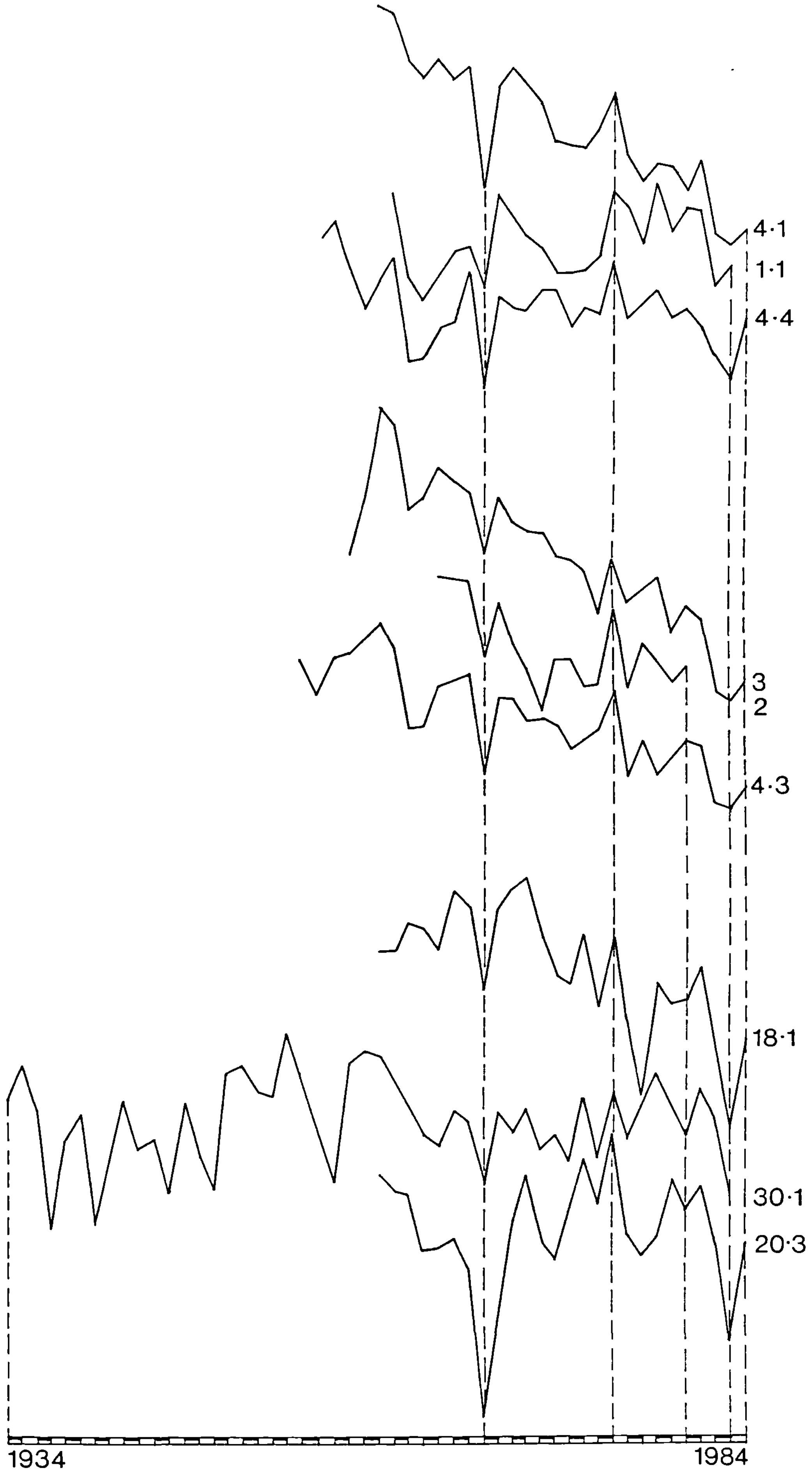


Fig.31 Modern alder; missing outer year-rings

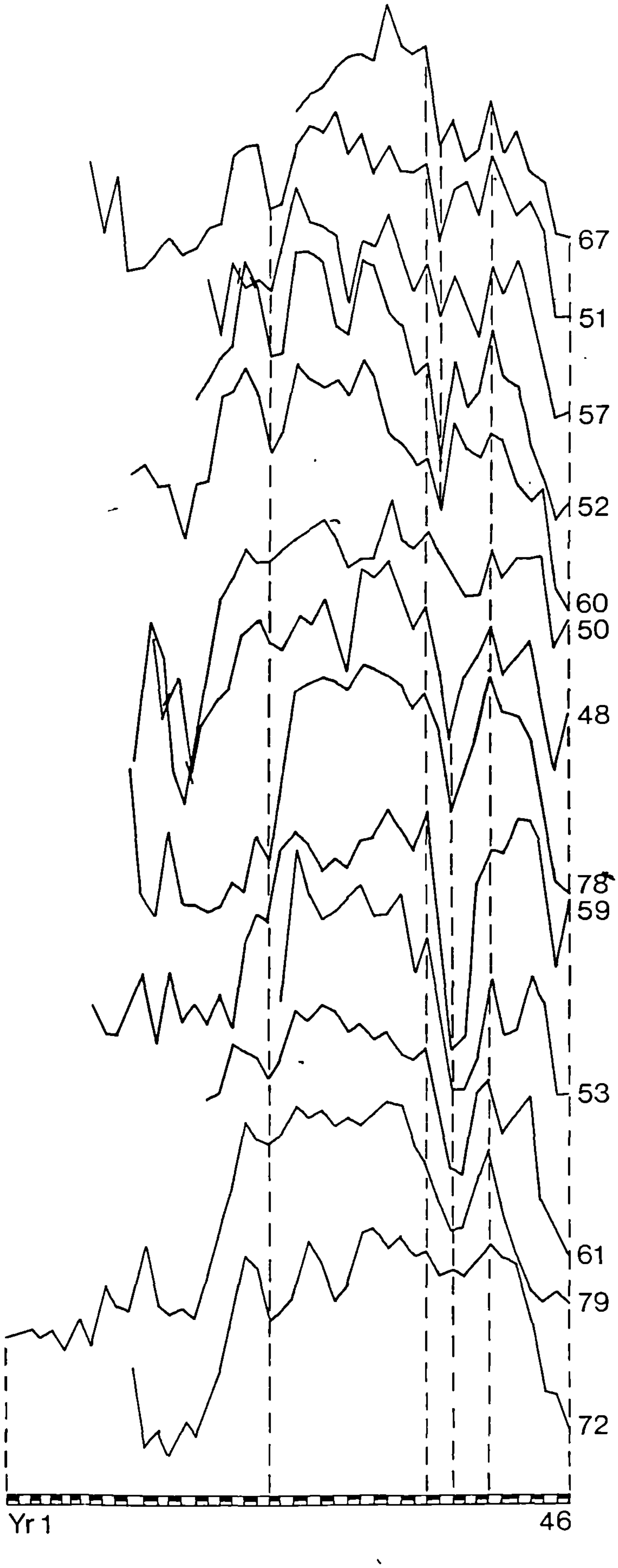


Fig.32 Moynagh Lough oak; SUBFAL2

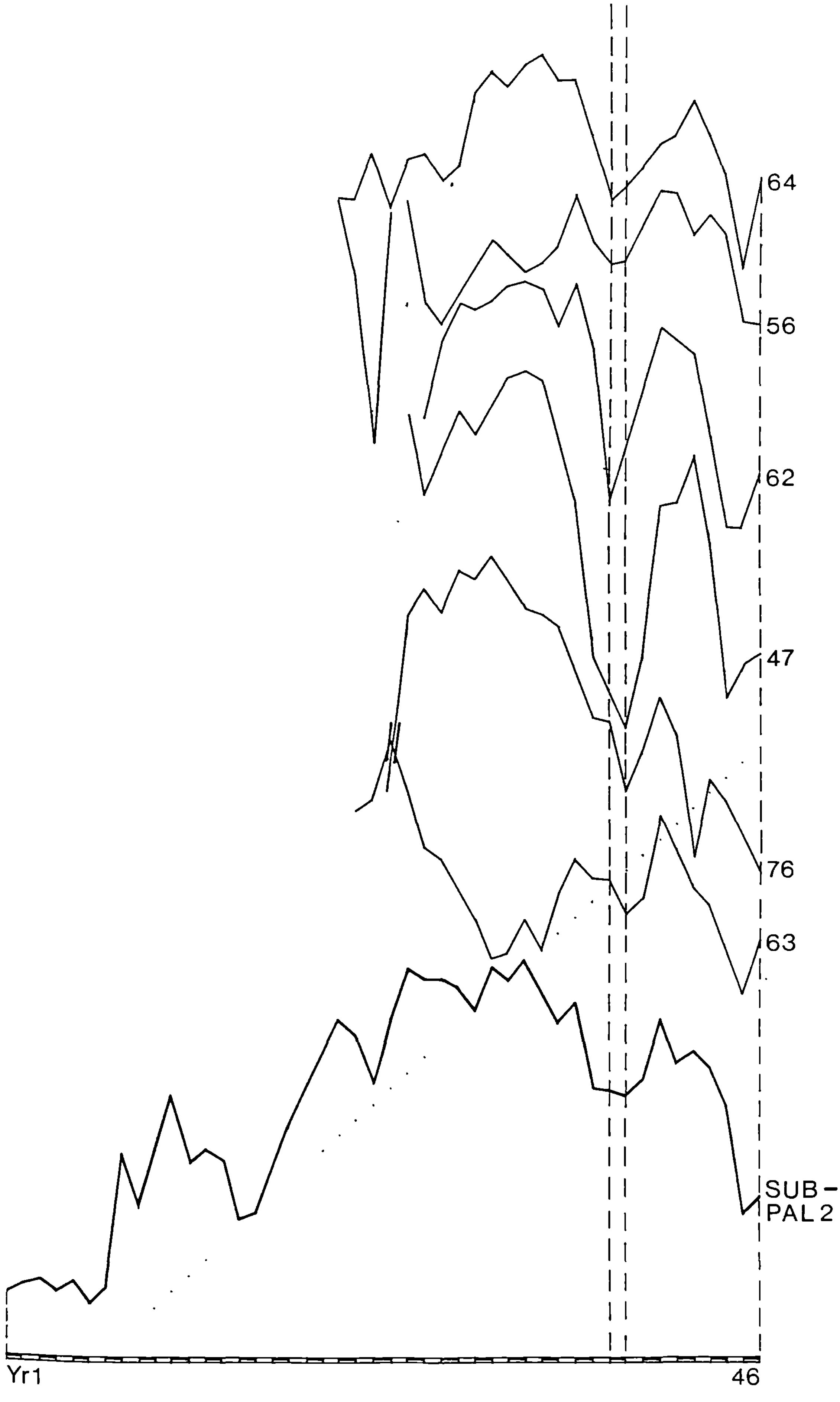


Fig.33 Moynagh Lough oak; correlations with SUBPAL2

Fig.34 Moynagh Lough oak; Palisade 2 correlations

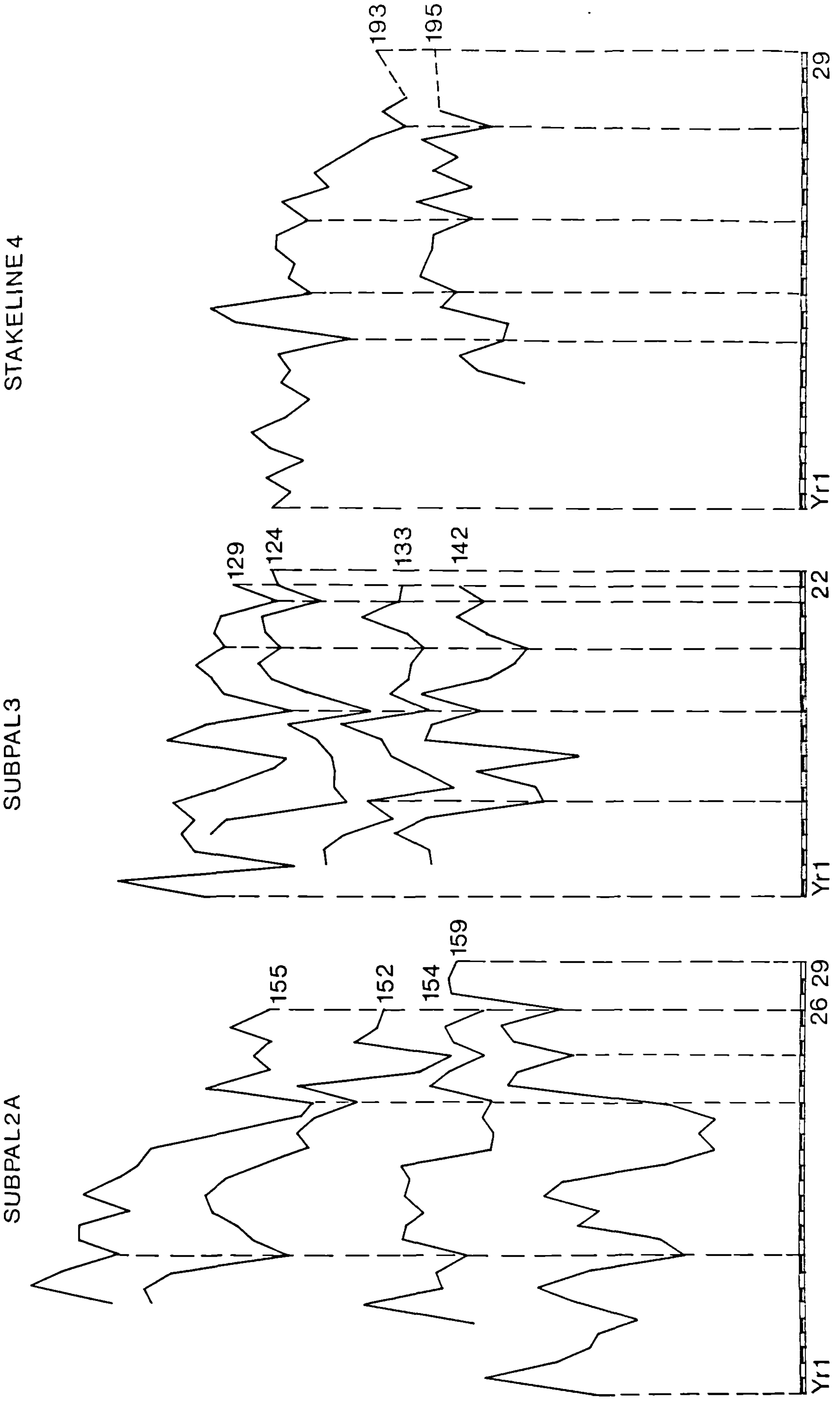


Fig.35 Moynagh Lough oak; SUBPAL2A, SUBPAL3 and Stakeline 4

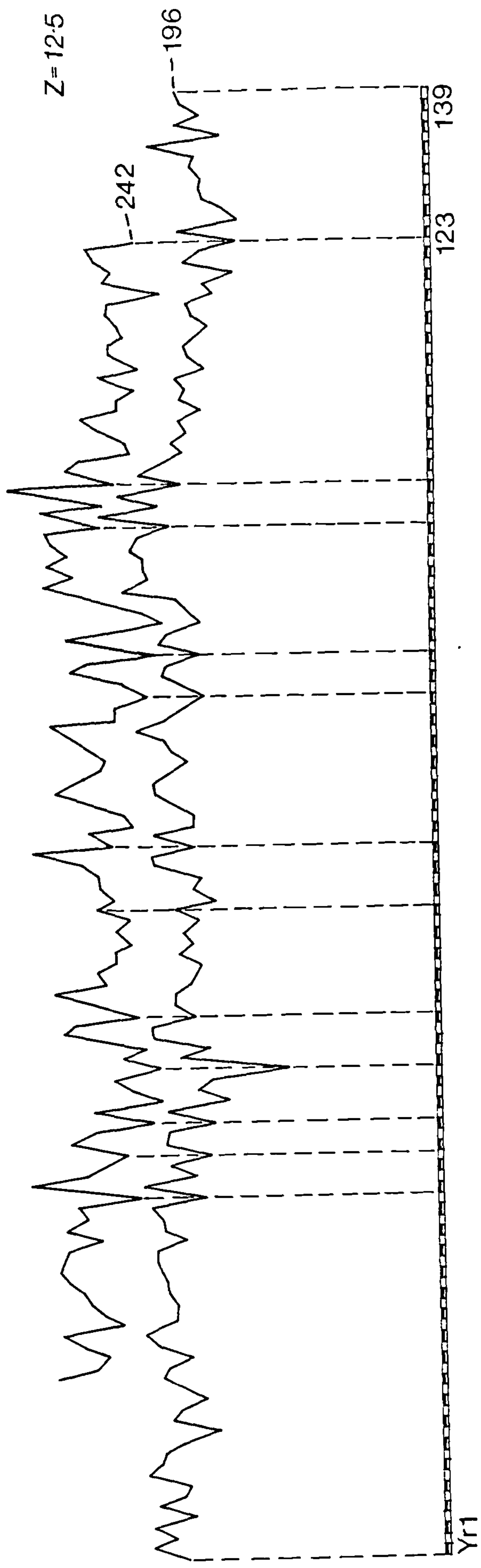


Fig.36 Moynagh Lough oak; Samples 196 and 242

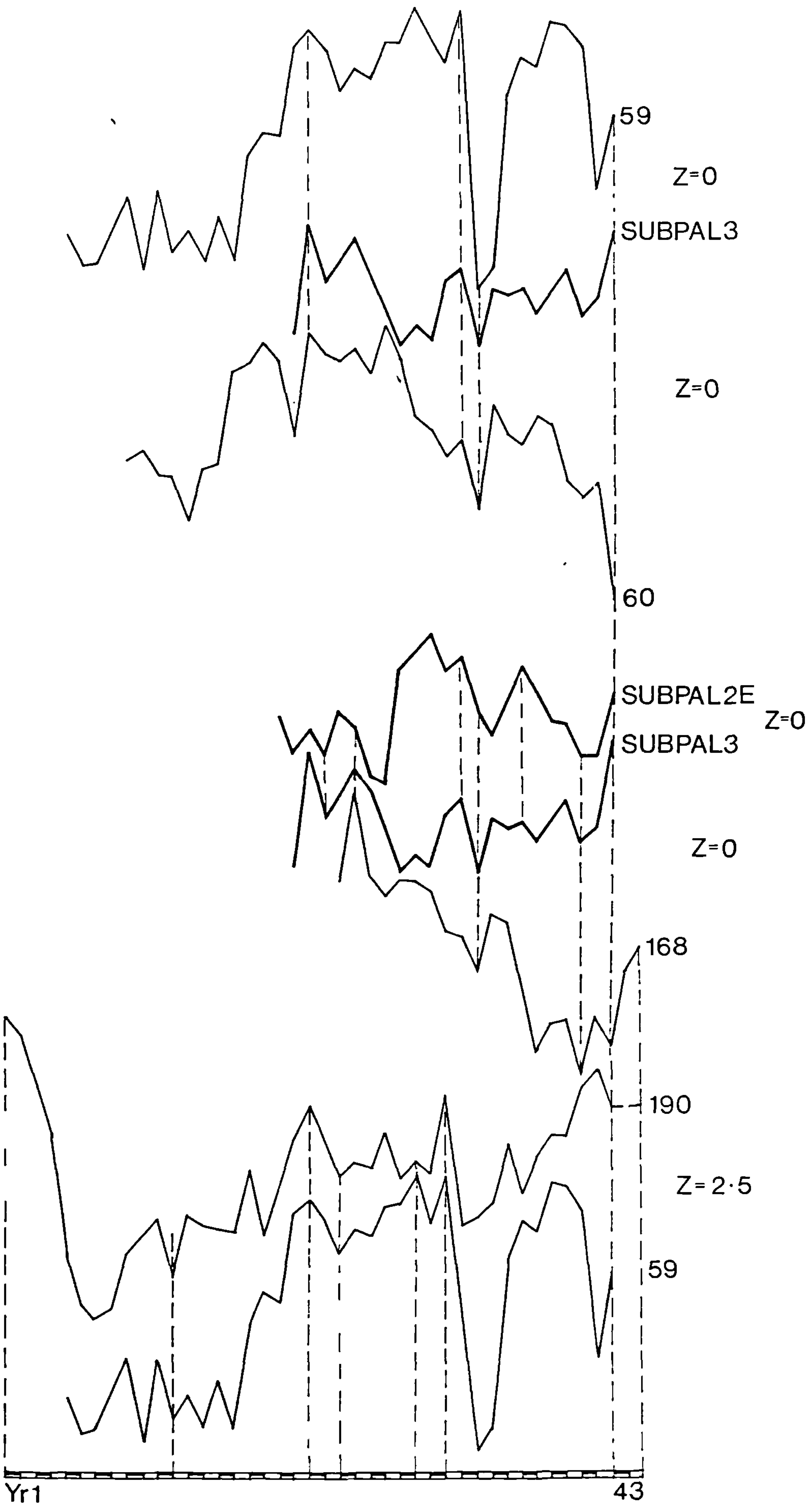


Fig.37 Moynagh Lough oak; Palisades 1, 2 and 3

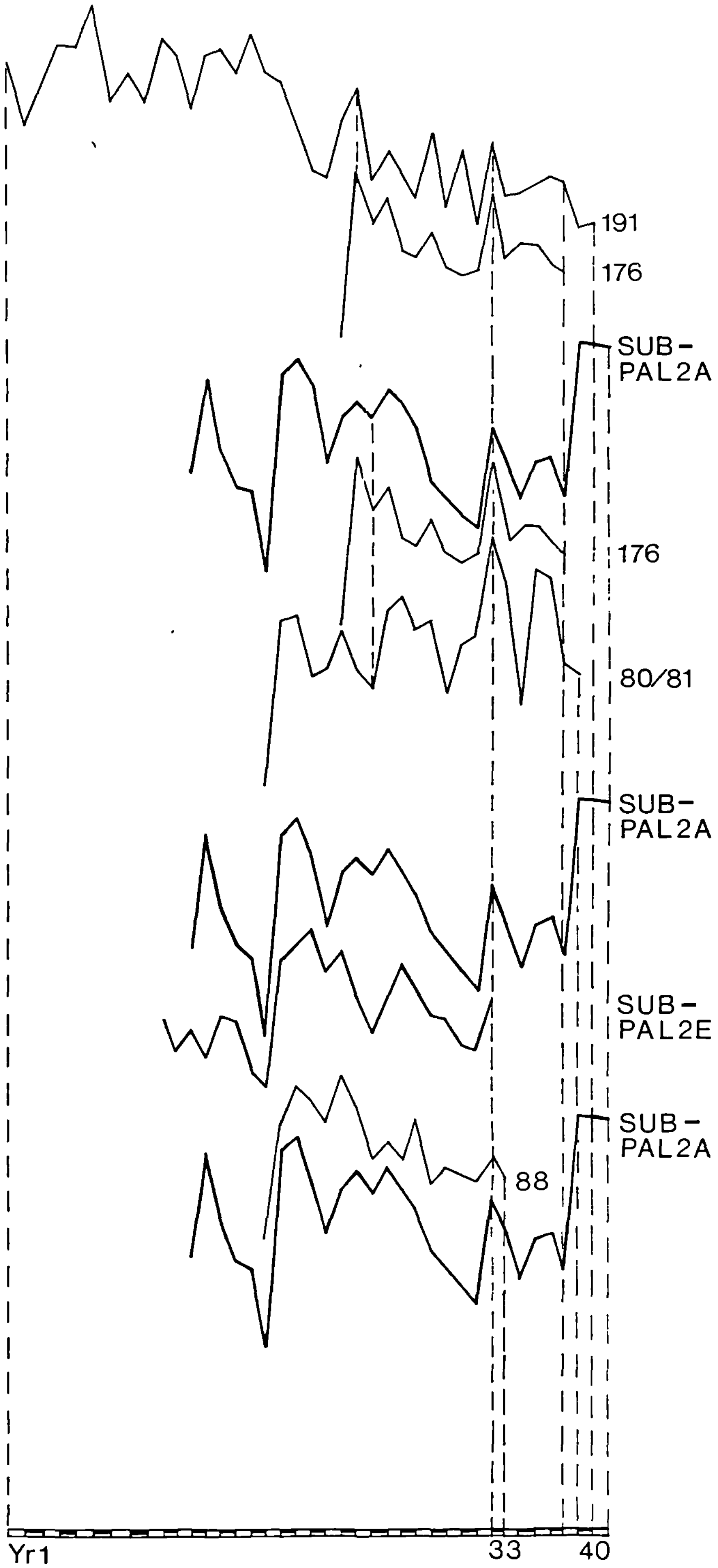


Fig.38 Moynagh Lough oak; Palisades 1, 2 and 3

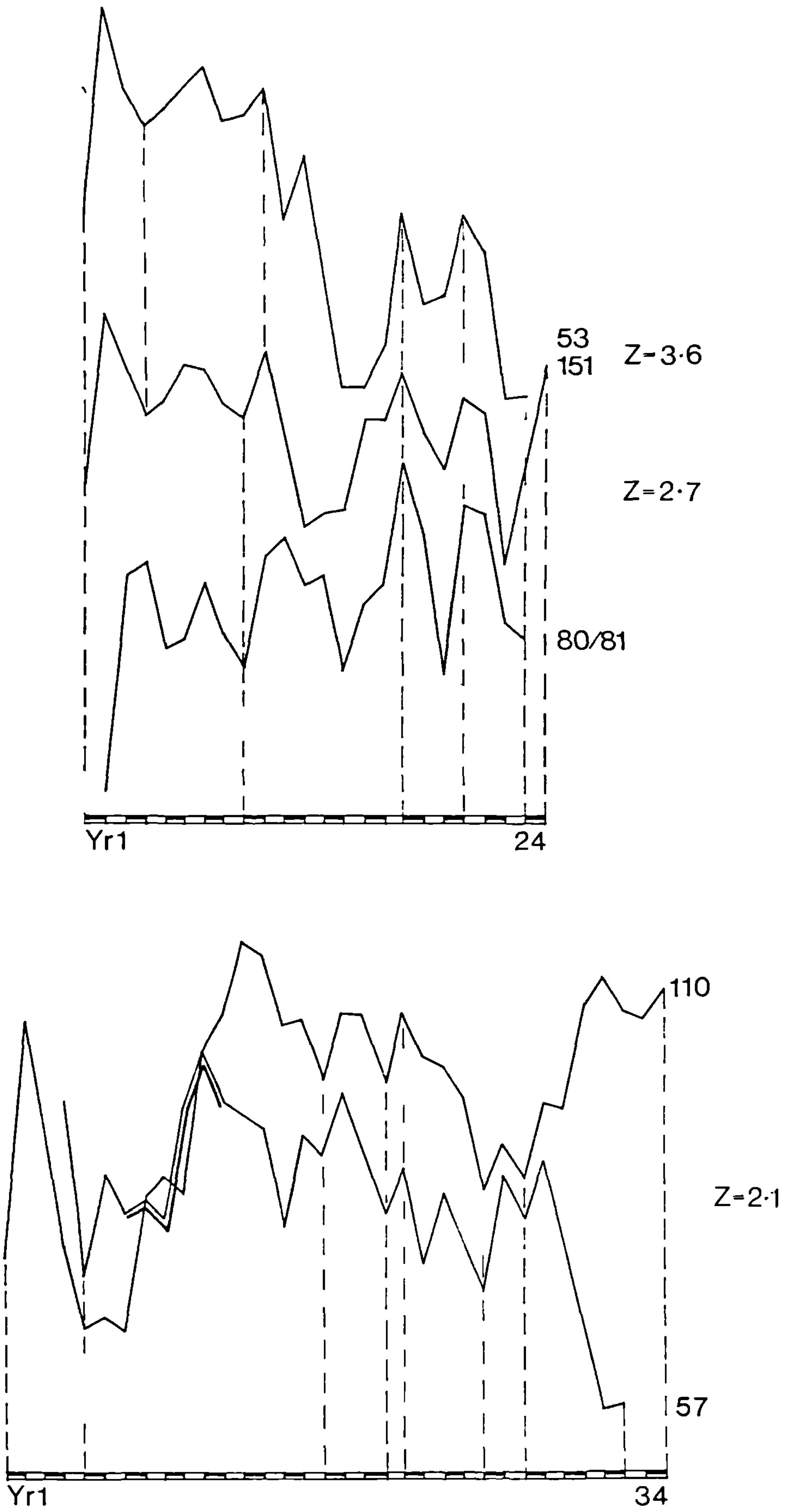


Fig.39 Moynagh Lough oak; Stakeline 3 correlations

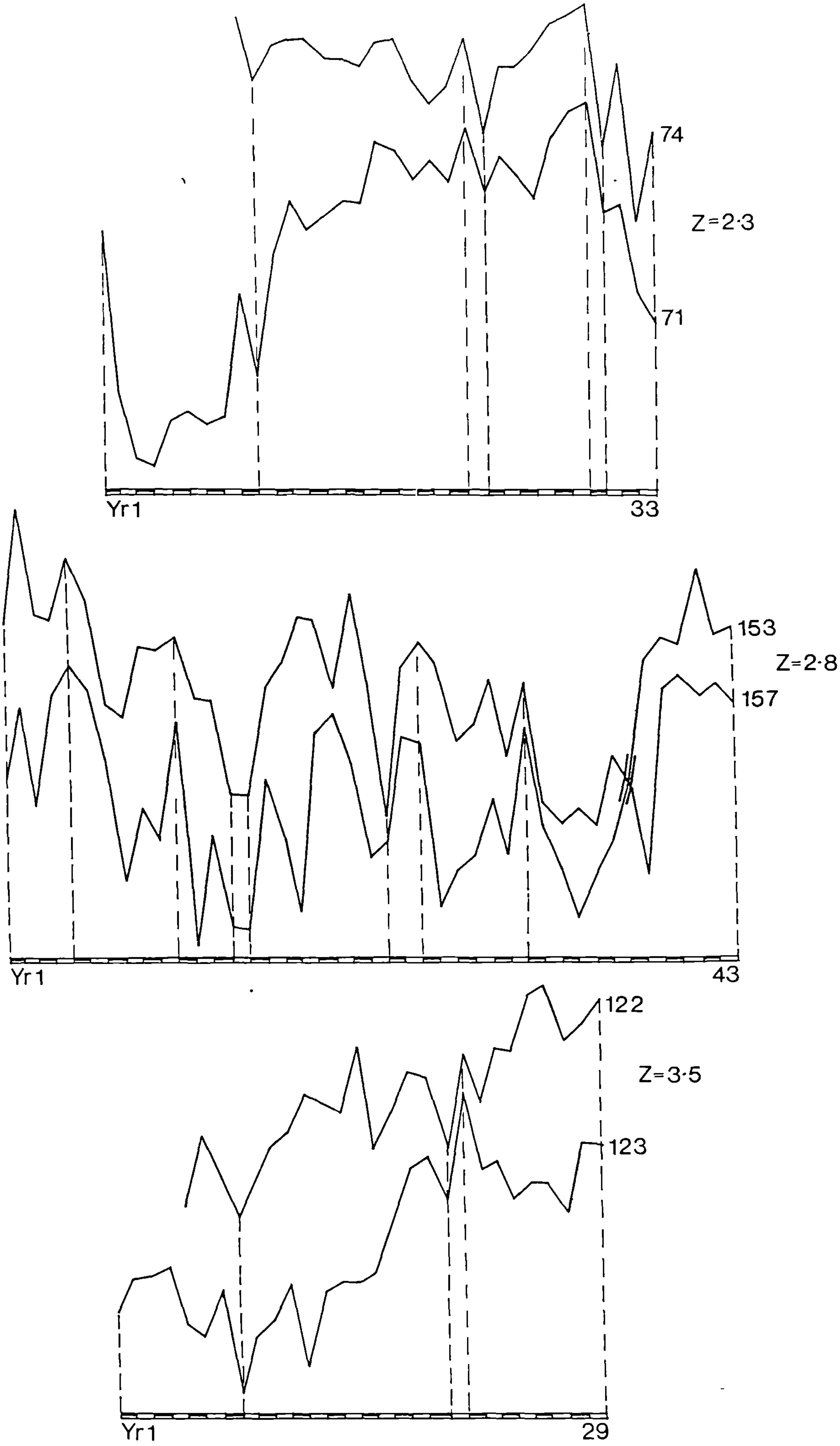


Fig.40 Moynagh Lough ash; Palisades 2, 2A and 3 correlations

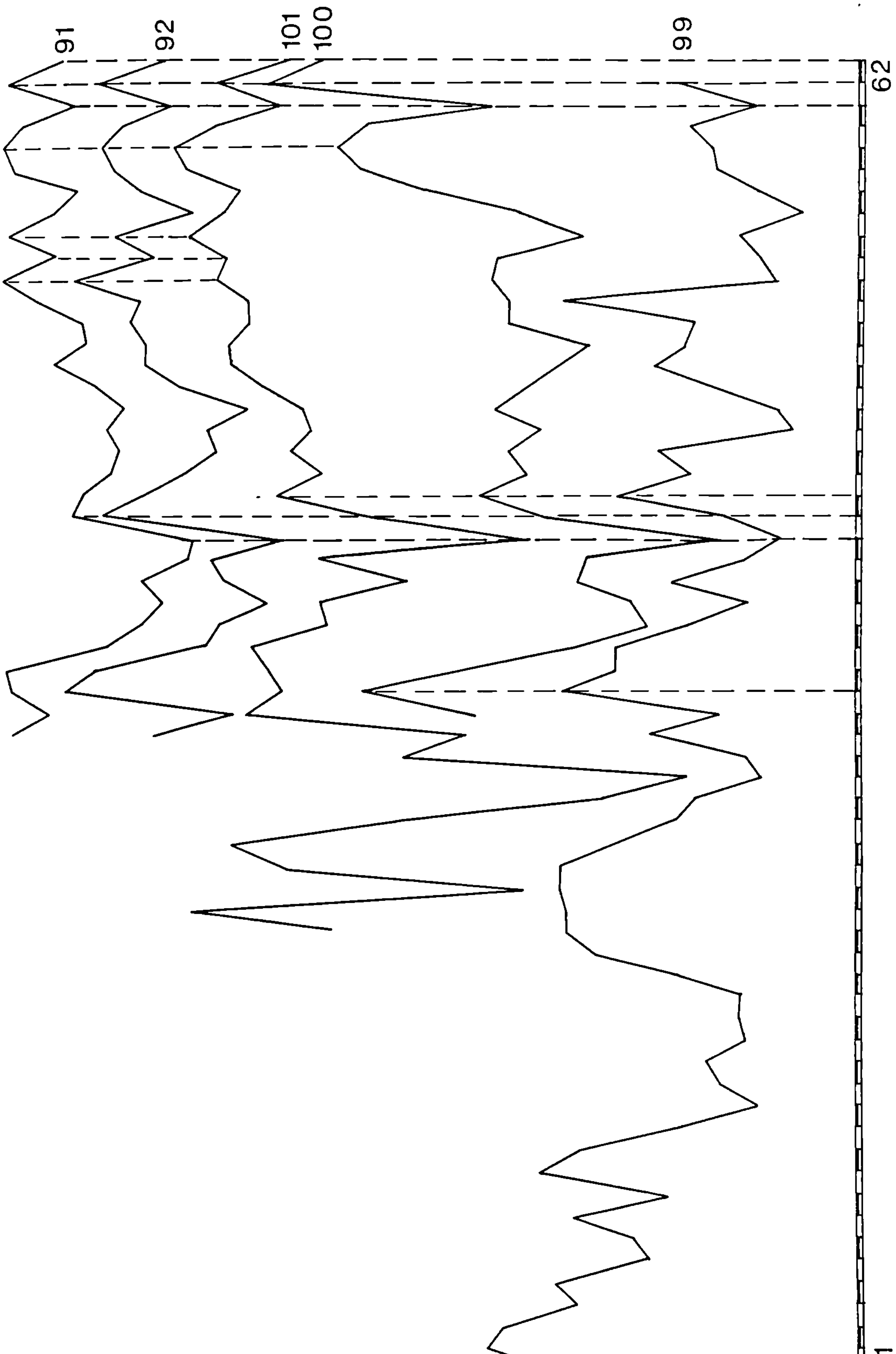
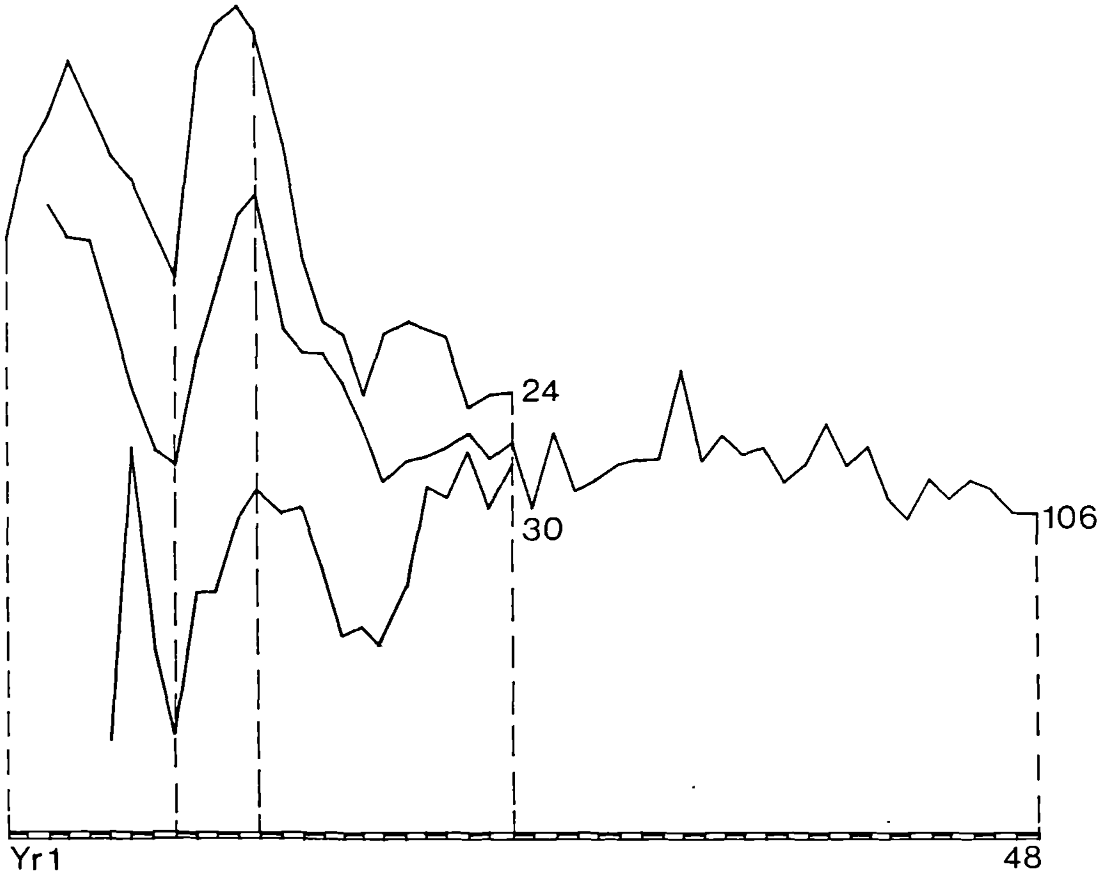


Fig.41 Moynagh Lough ash; Causeway correlations



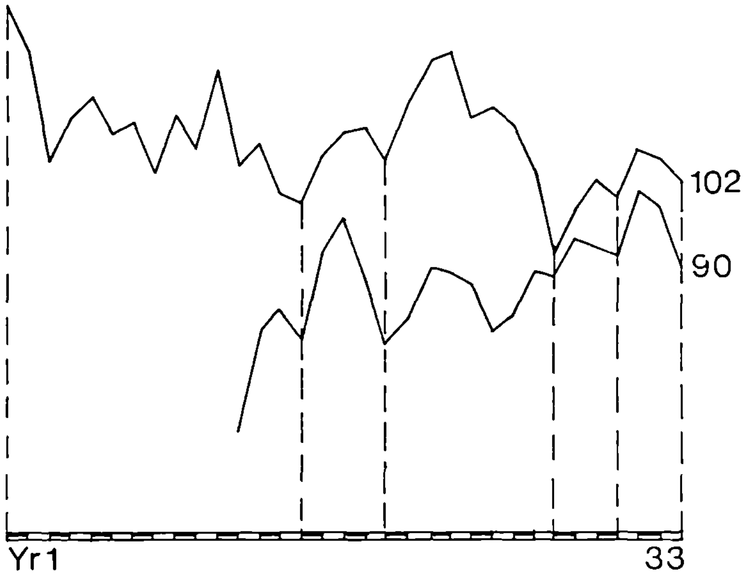


Fig.42 Moynagh Lough ash; Causeway correlations

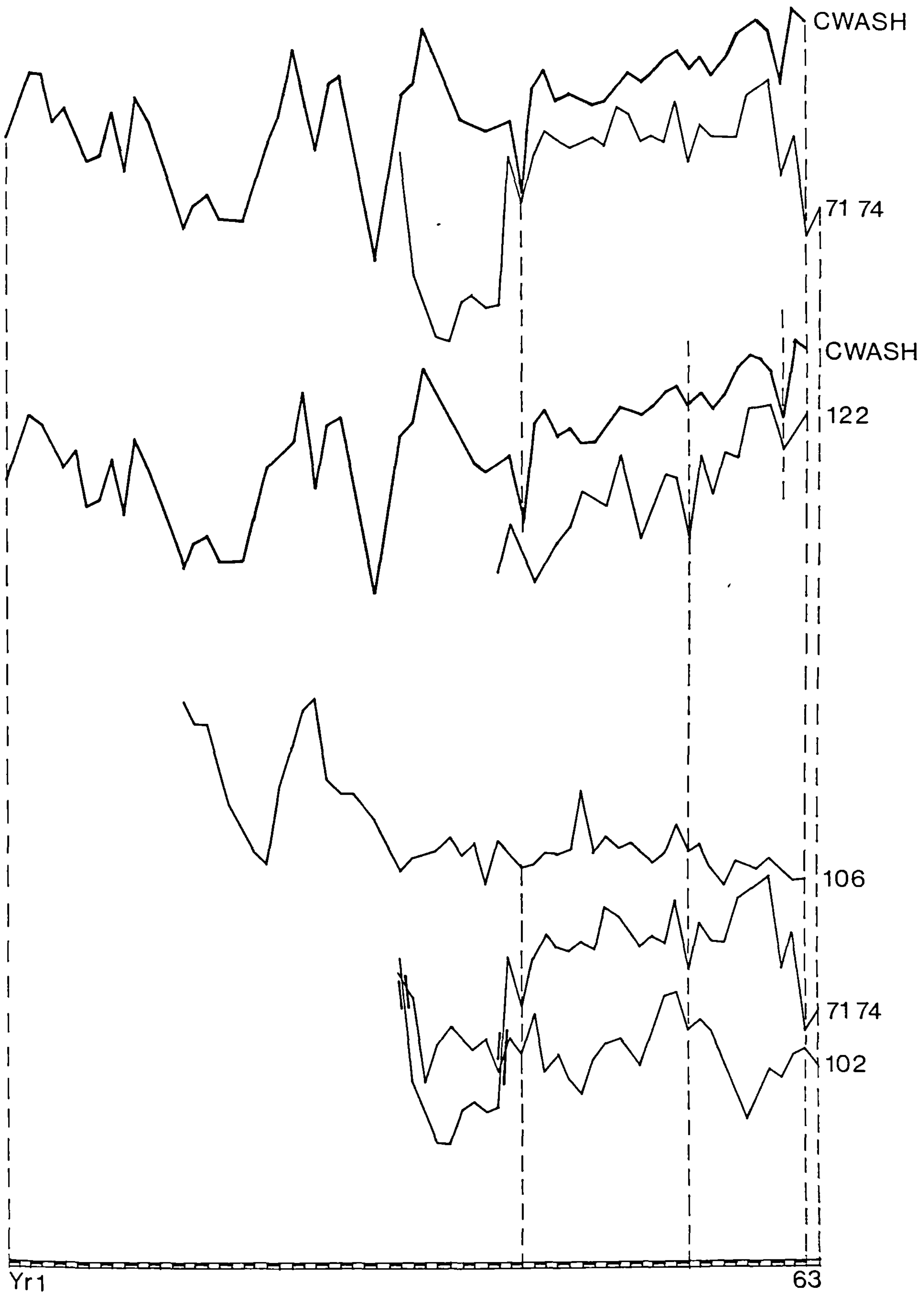


Fig.43 Moynagh Lough ash; correlations between Causeway and Palisade 2

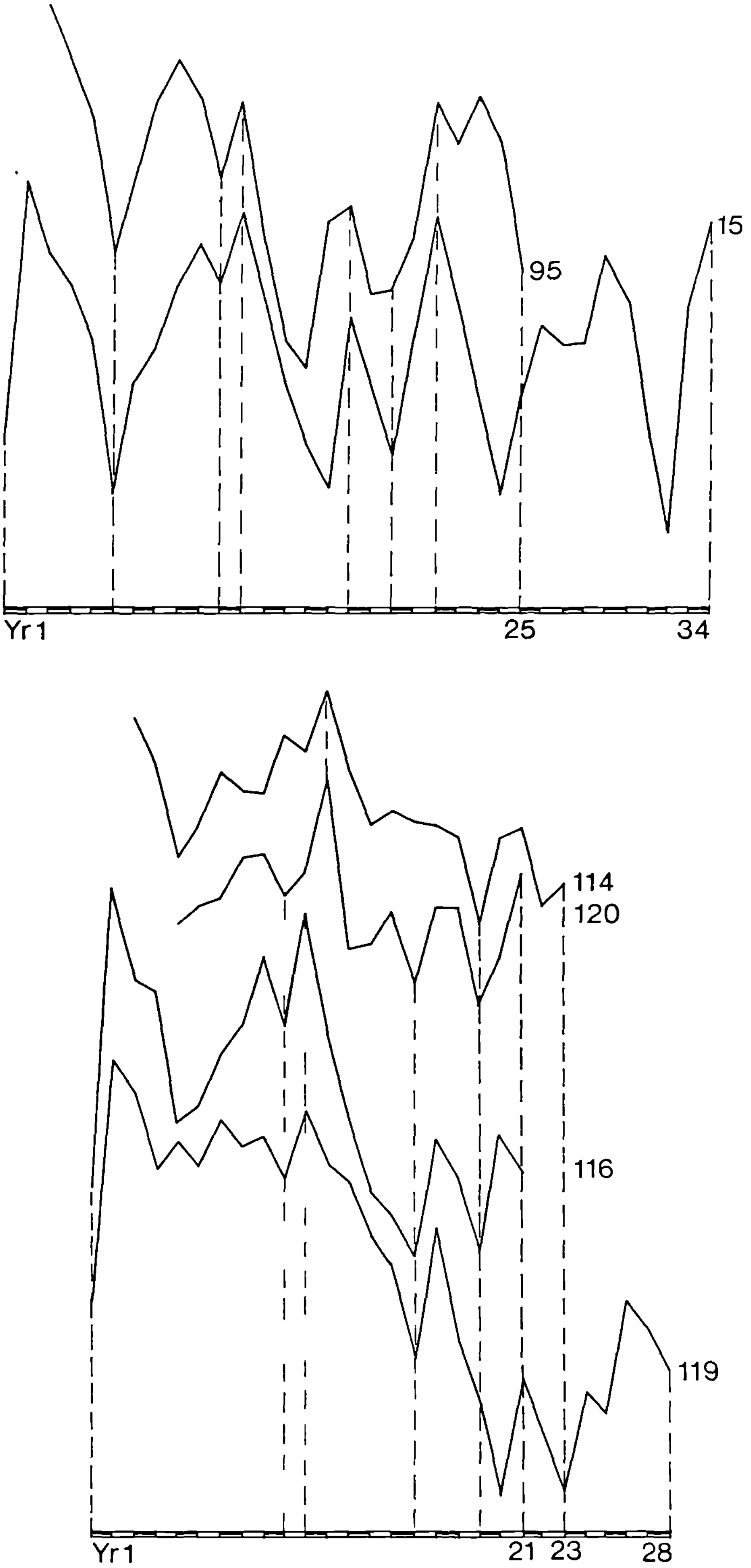


Fig.44 Moynagh Lough hazel; Causeway and Stakeline 1

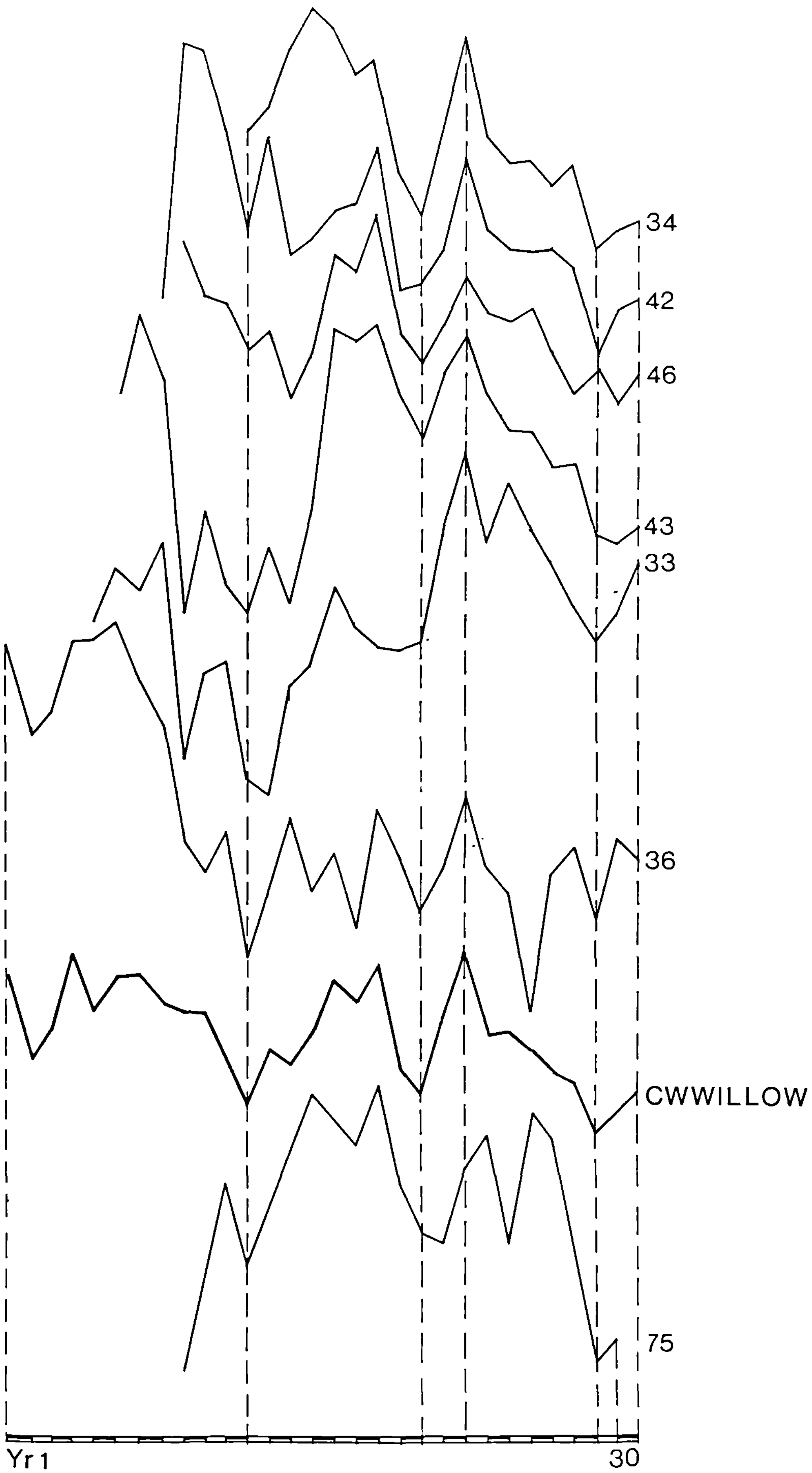
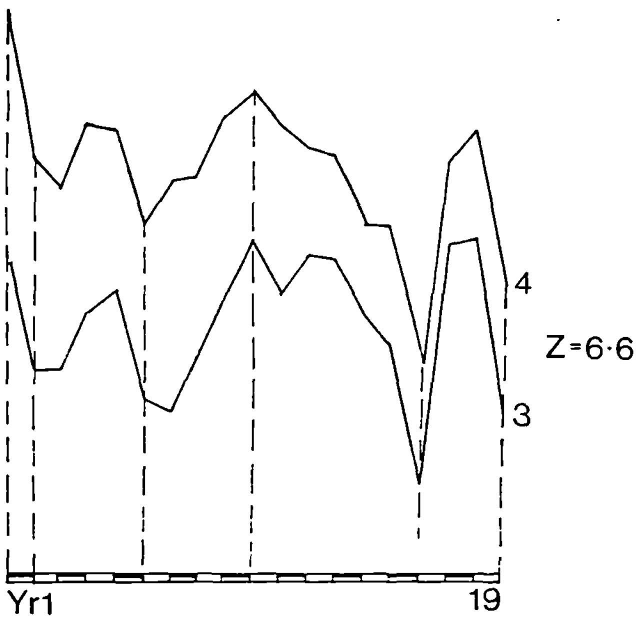


Fig.45 Moynagh Lough willow; Causeway correlations



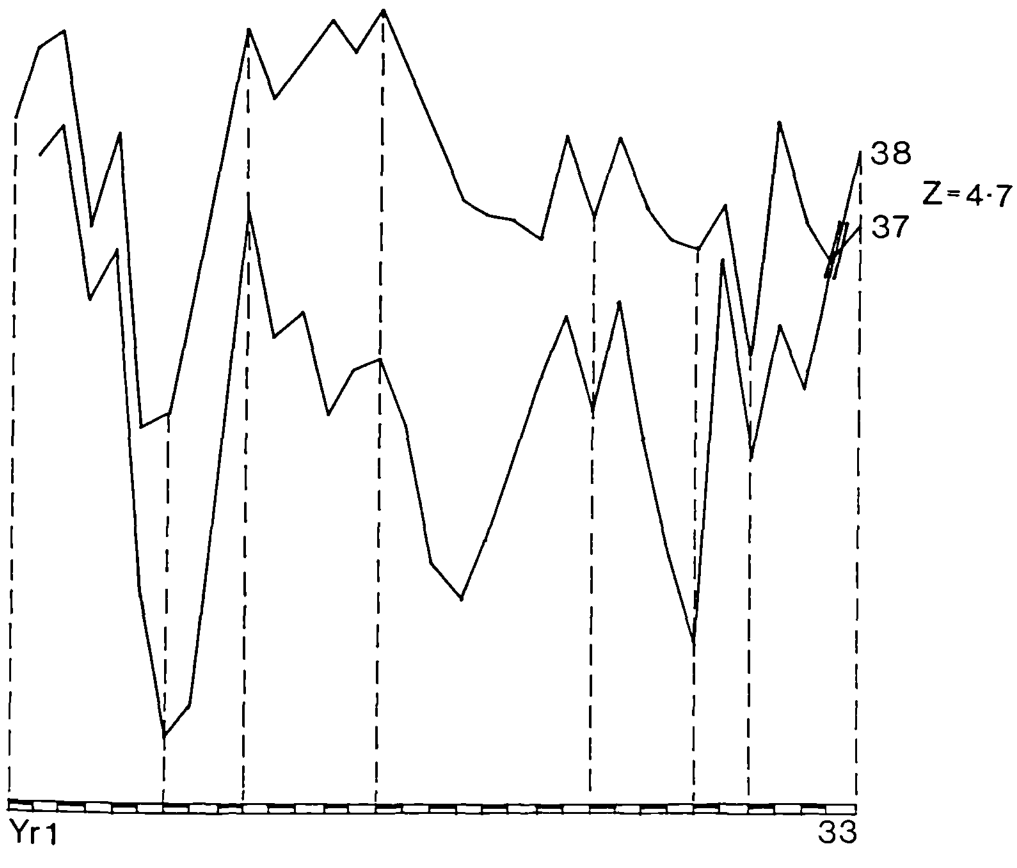


Fig.46 Moynagh Lough alder; Causeway correlations

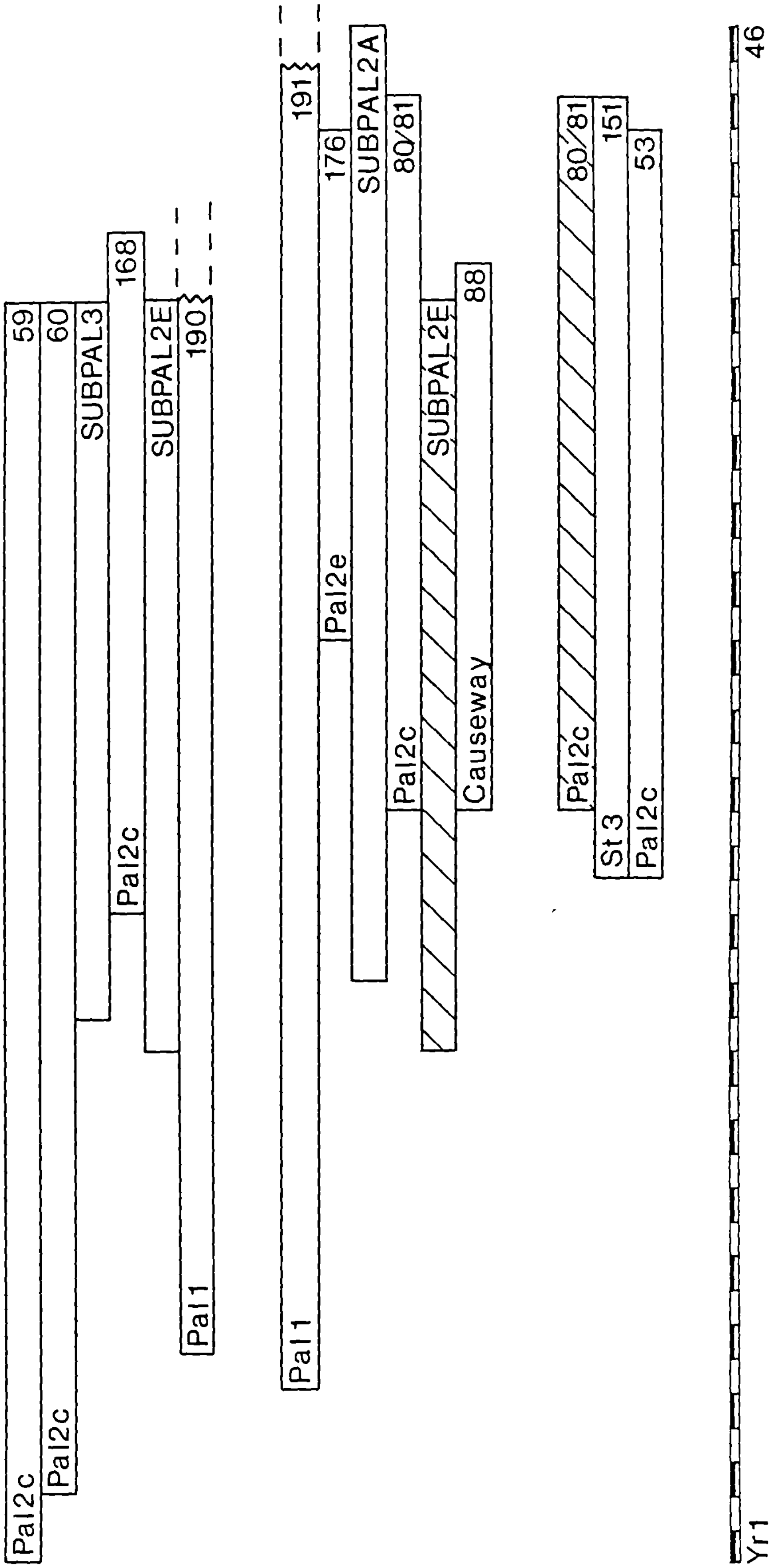


Fig.47 Moynagh Lough; site chronology

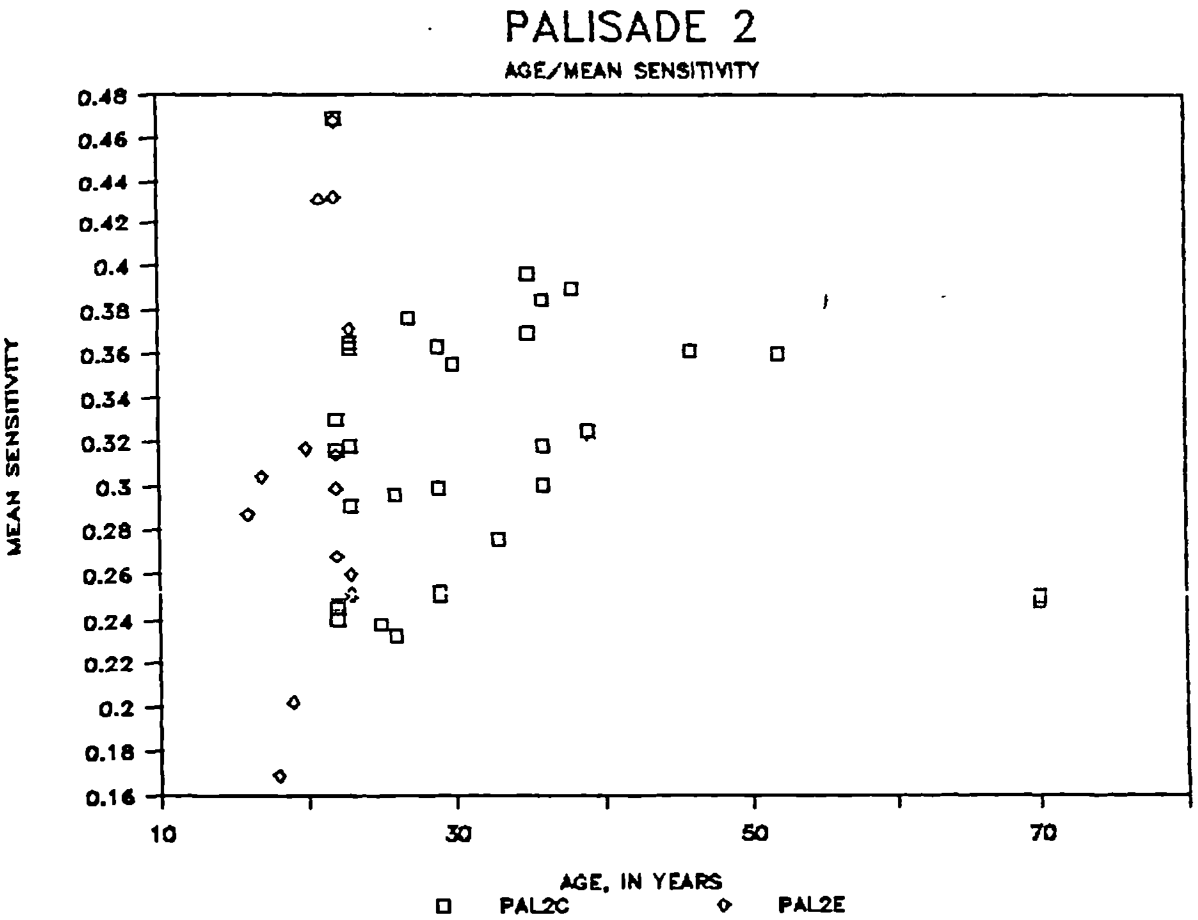
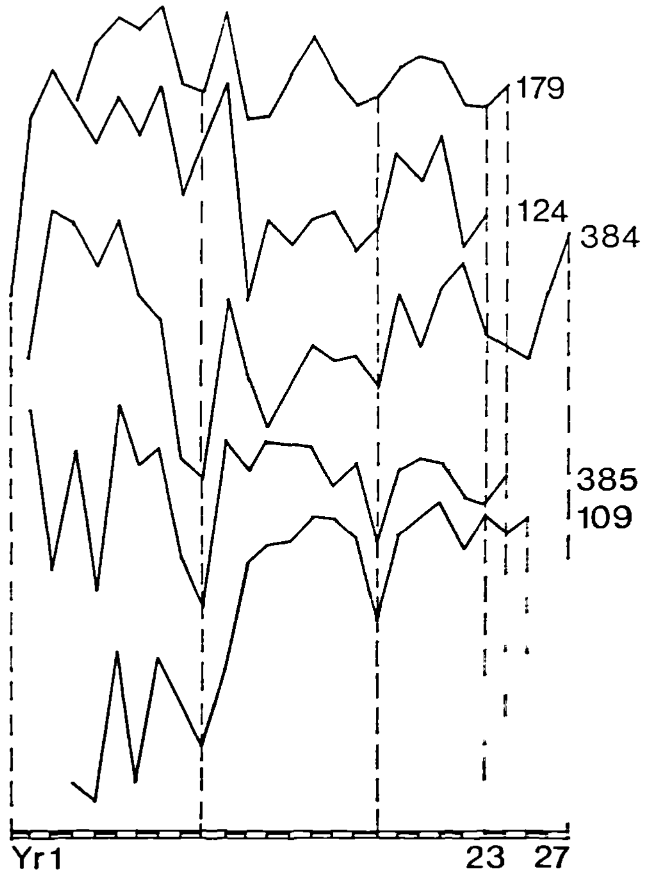


Fig.48 Moynagh Lough; age and mean sensitivity along Palisade 2



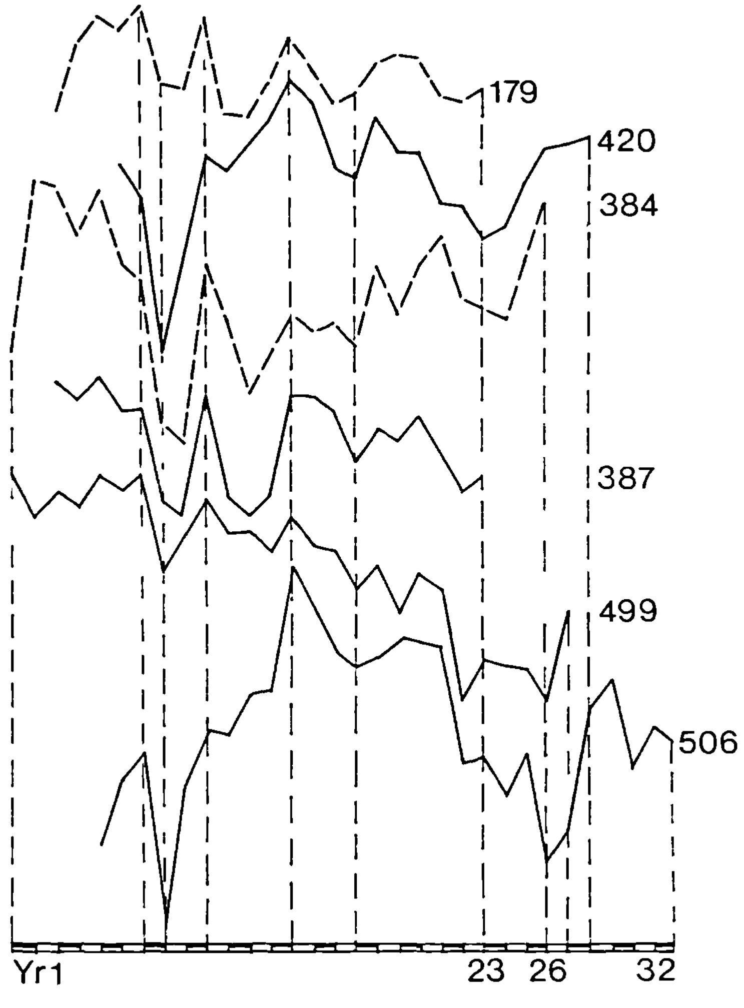


Fig.49 Oakbank alder; Blocks 1 and 2

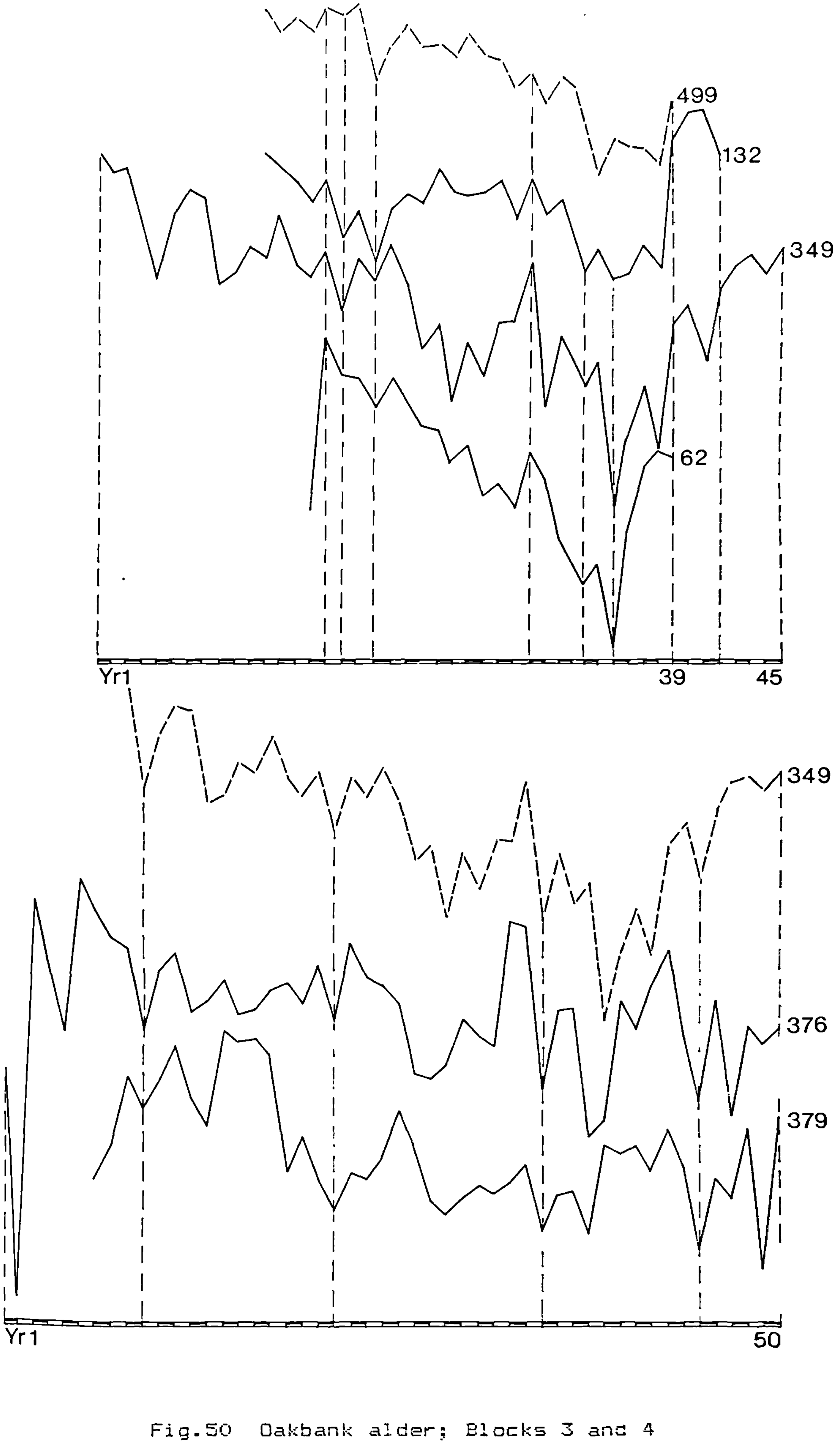
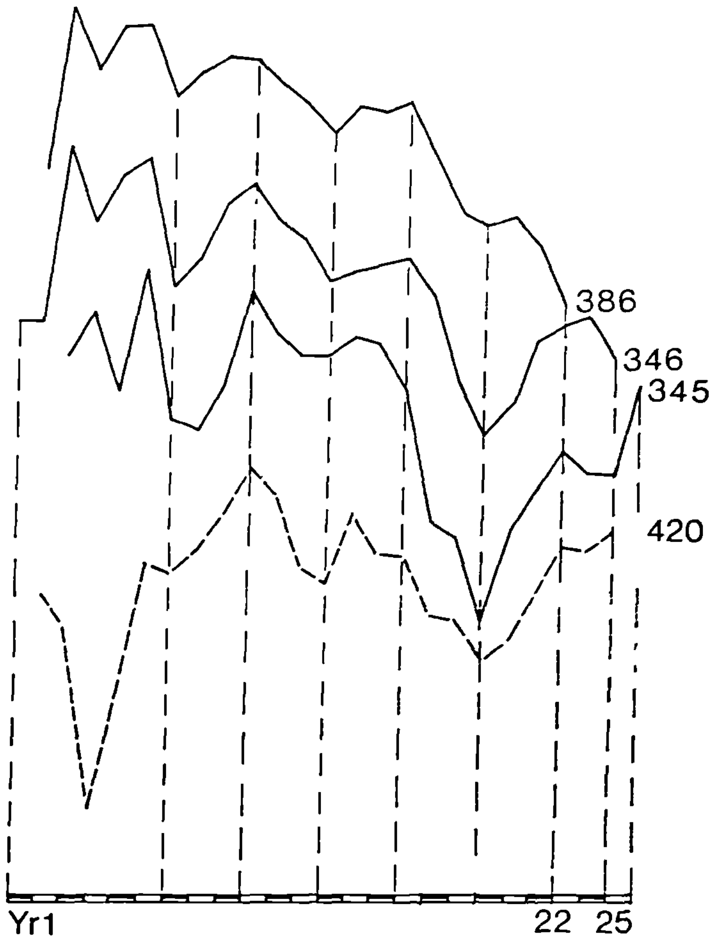


Fig.50 Oakbank alder; Blocks 3 and 4



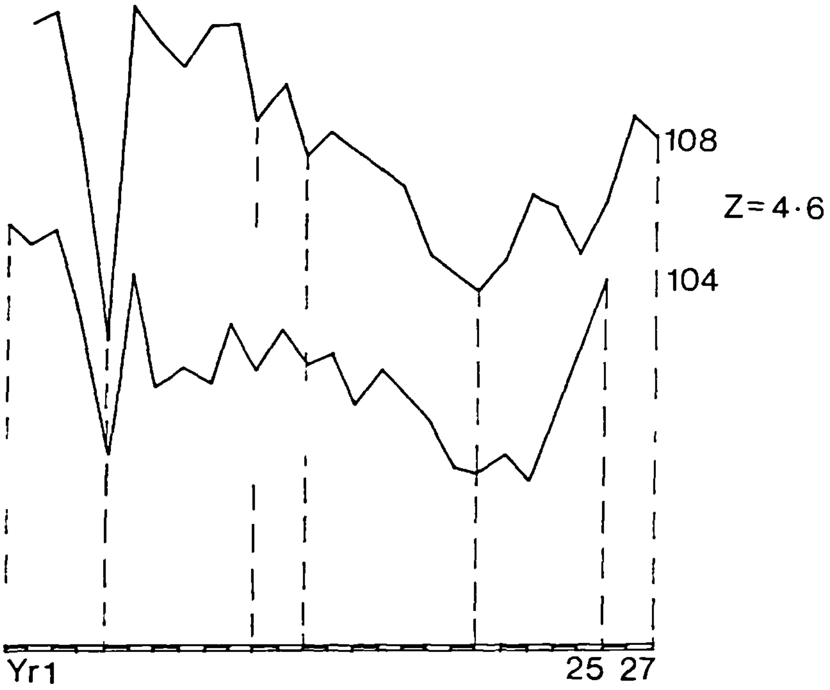


Fig.51 Oakbank alder; Blocks 5 and 8

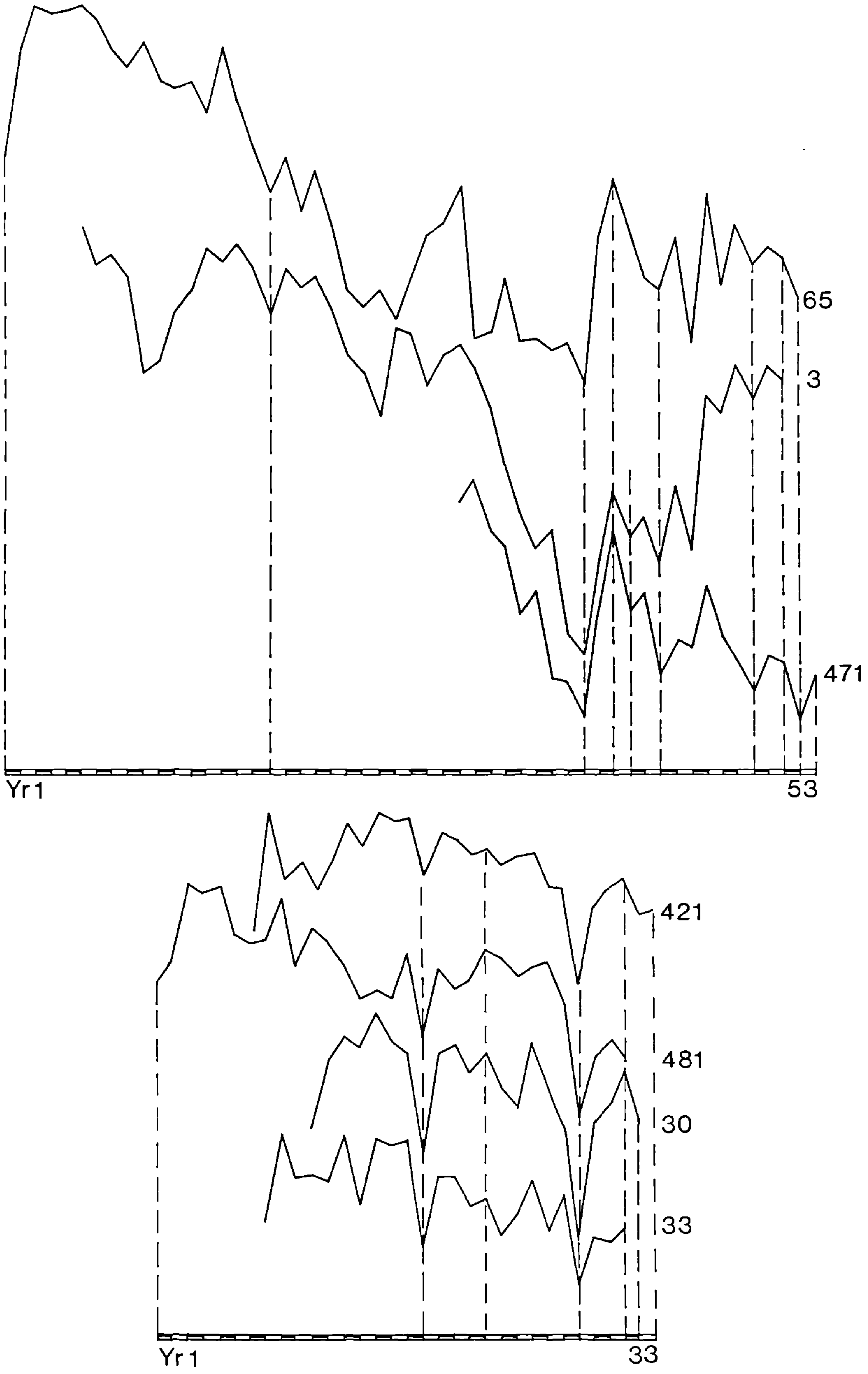


Fig.52 Oakbank alder; Blocks 6 and 7

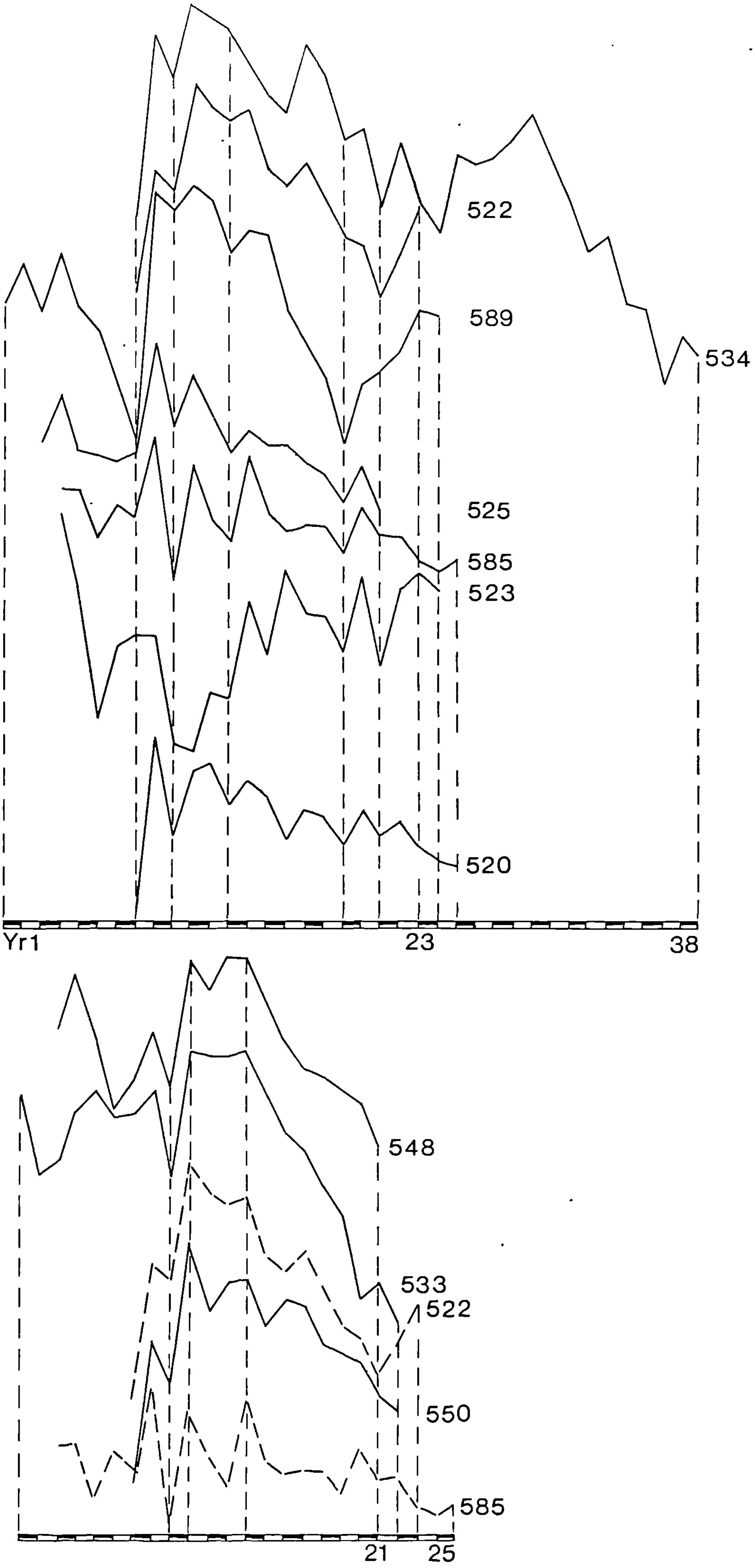


Fig.53 Oakbank alder; Blocks 9 and 12

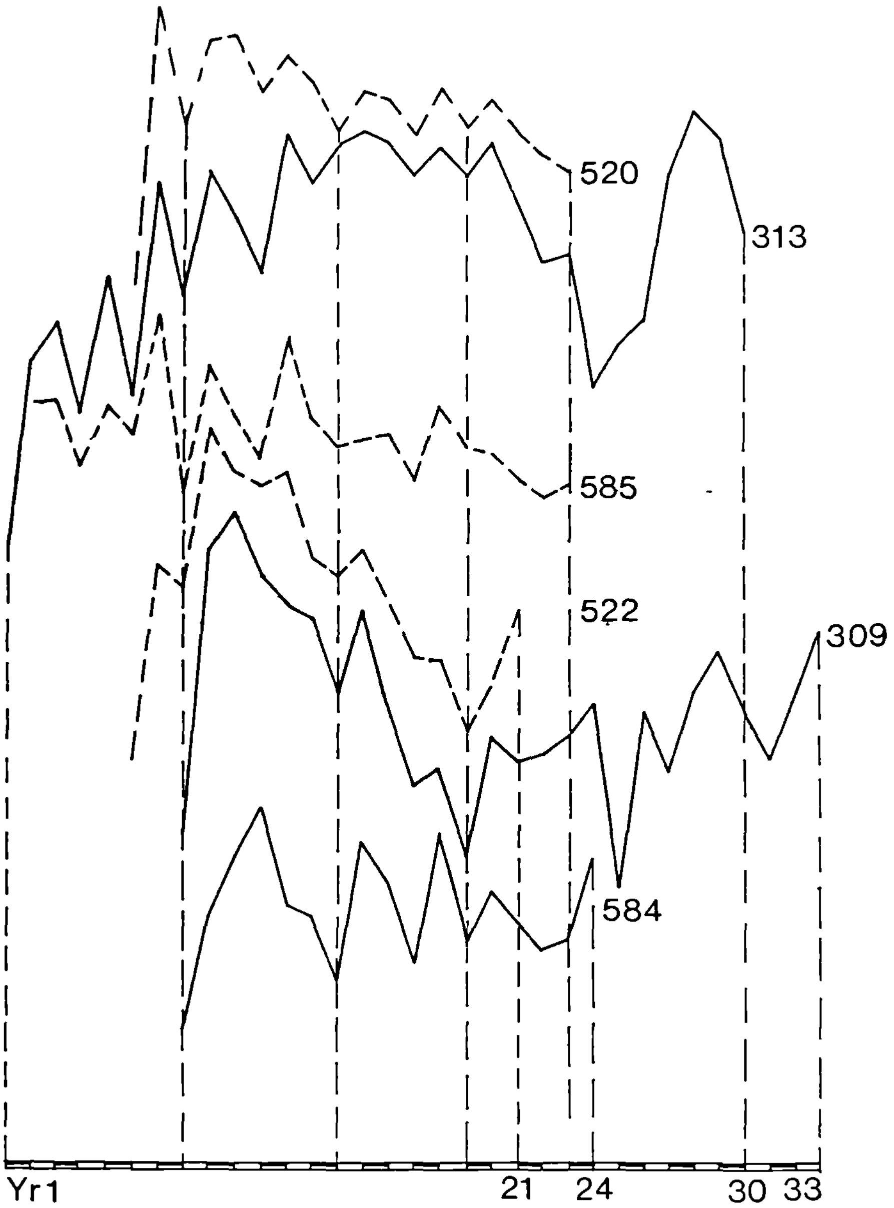


Fig.54 Oakbank alder; Block 10

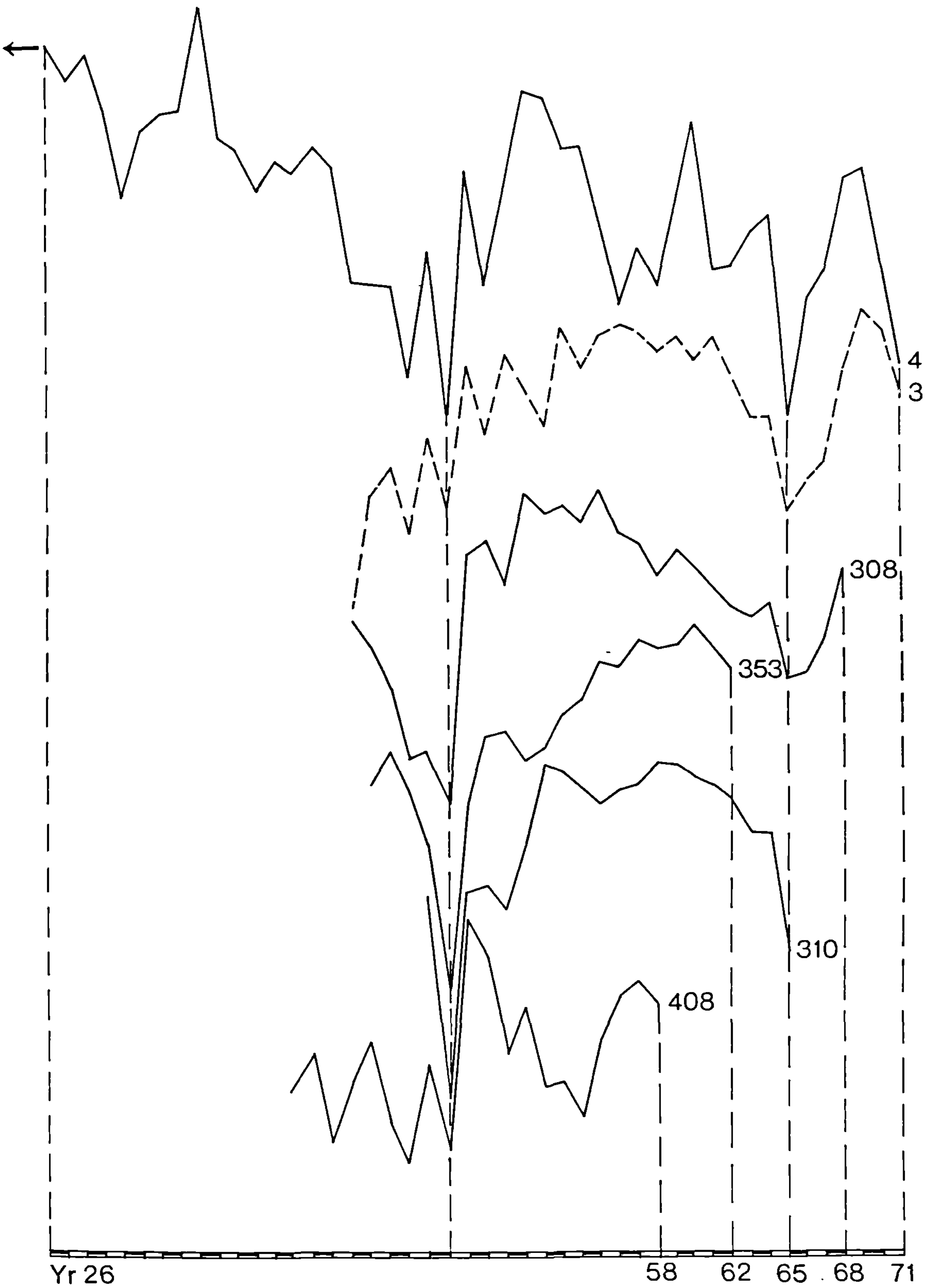
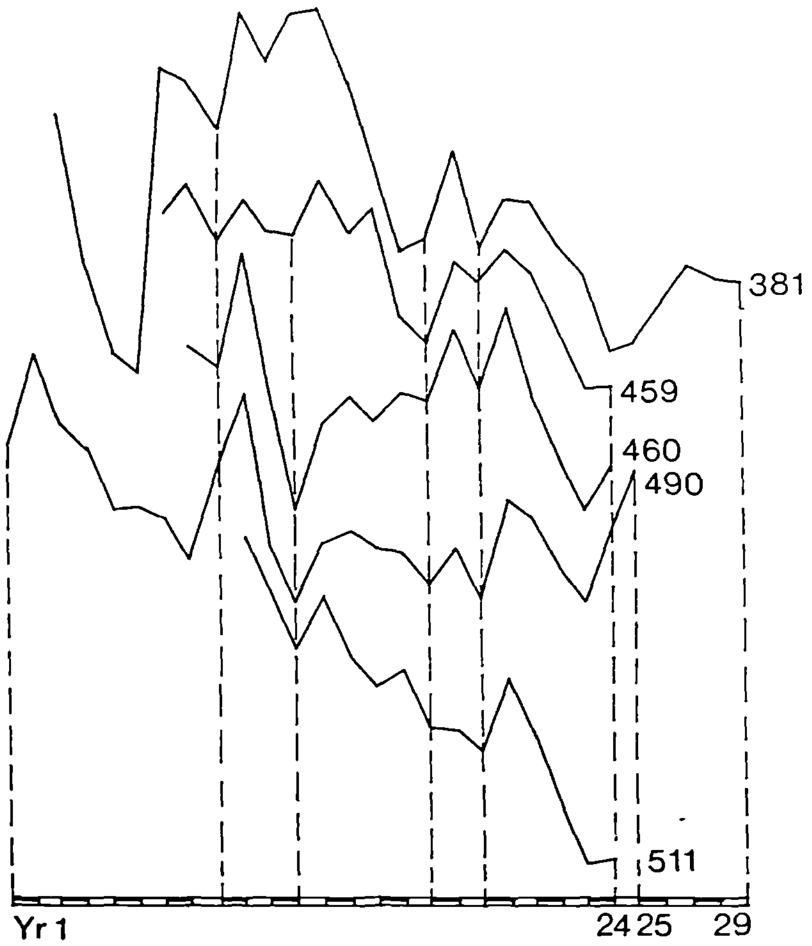


Fig.55 Oakbank alder; Block 11



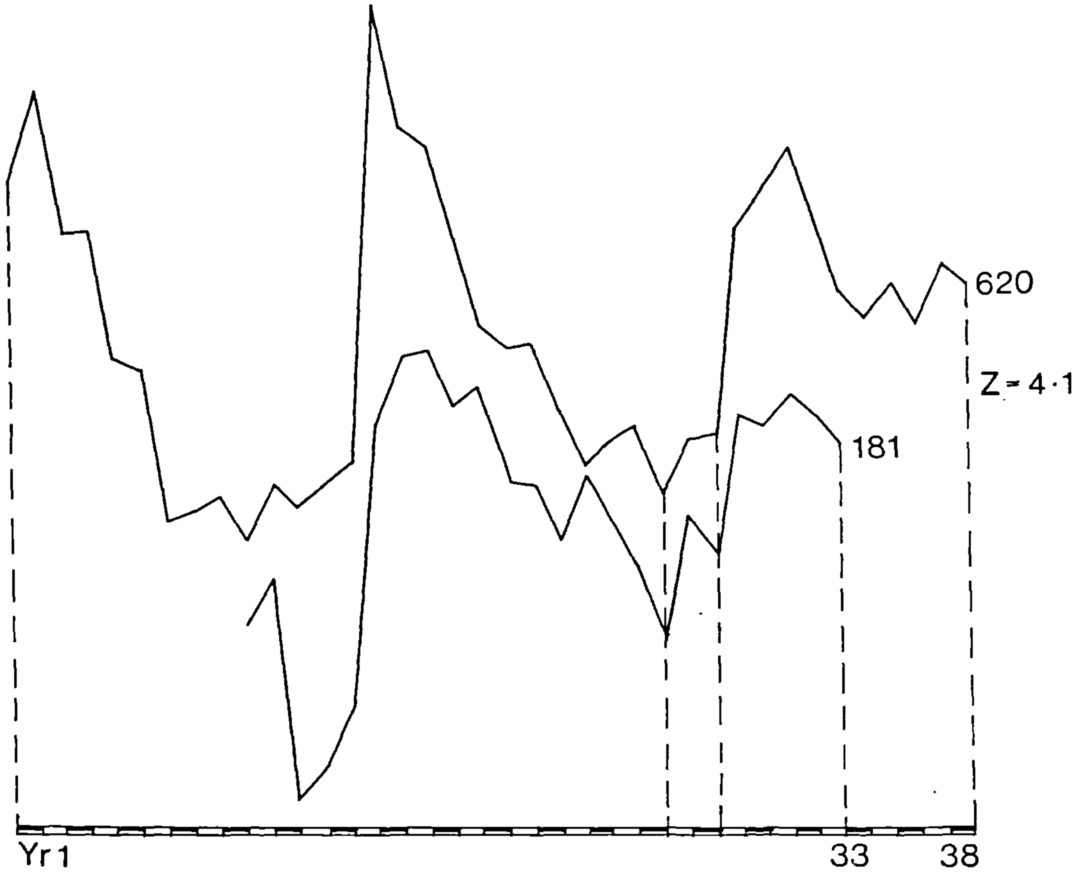


Fig.56 Oakbank alder; Blocks 13 and 14

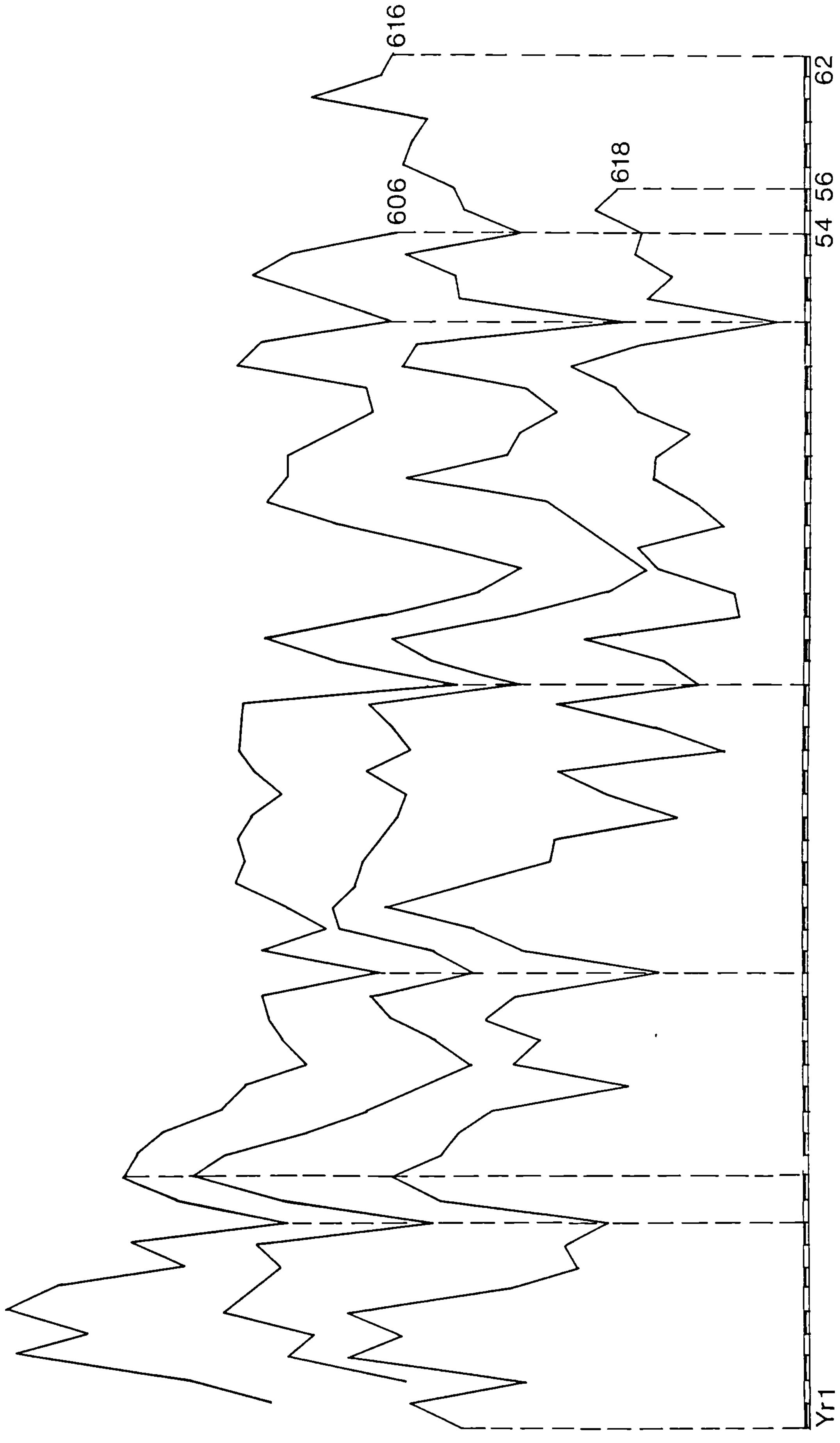


Fig.57 Oakbank alder; Block 15

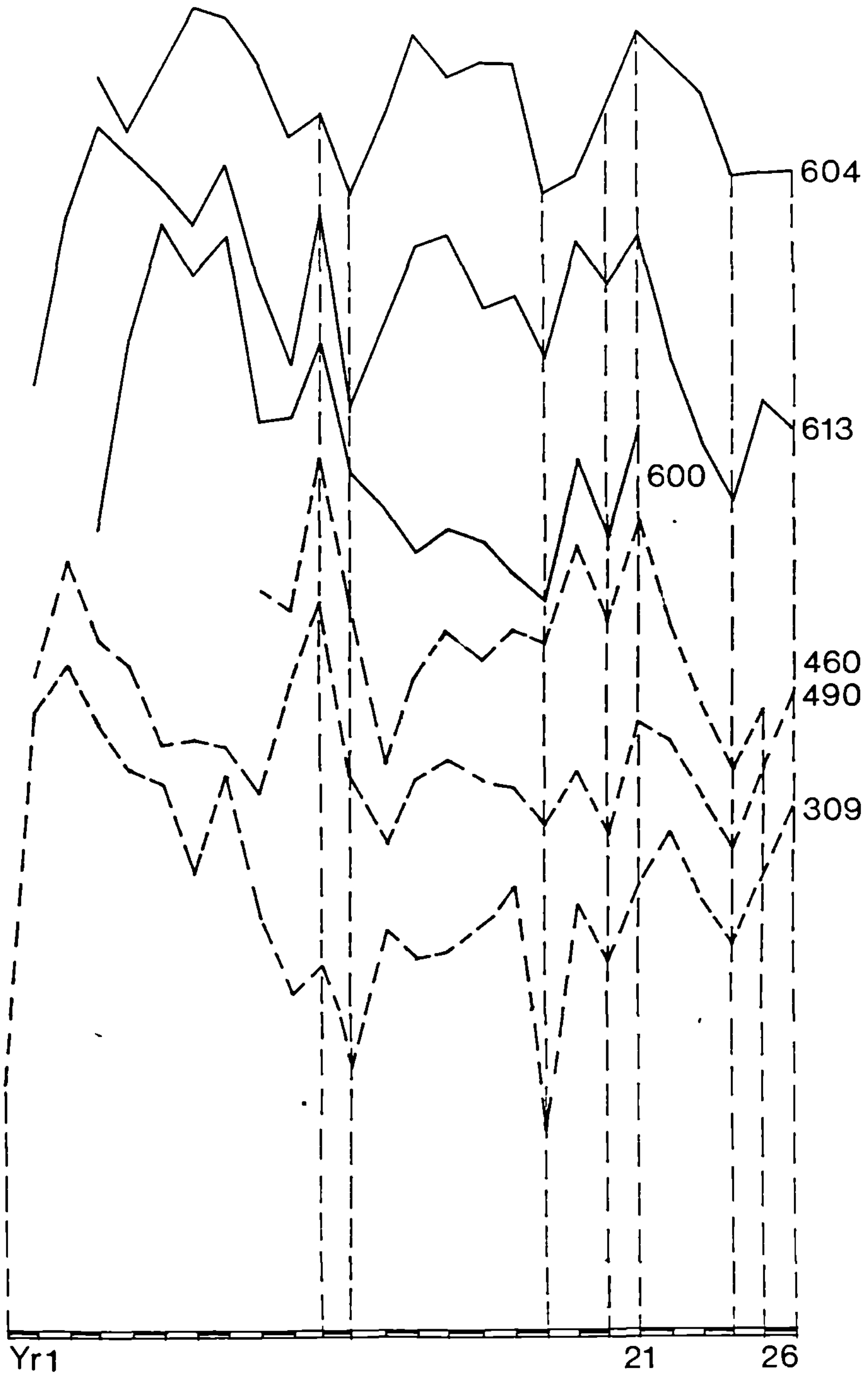


Fig.58 Oakbank alder; Block 16

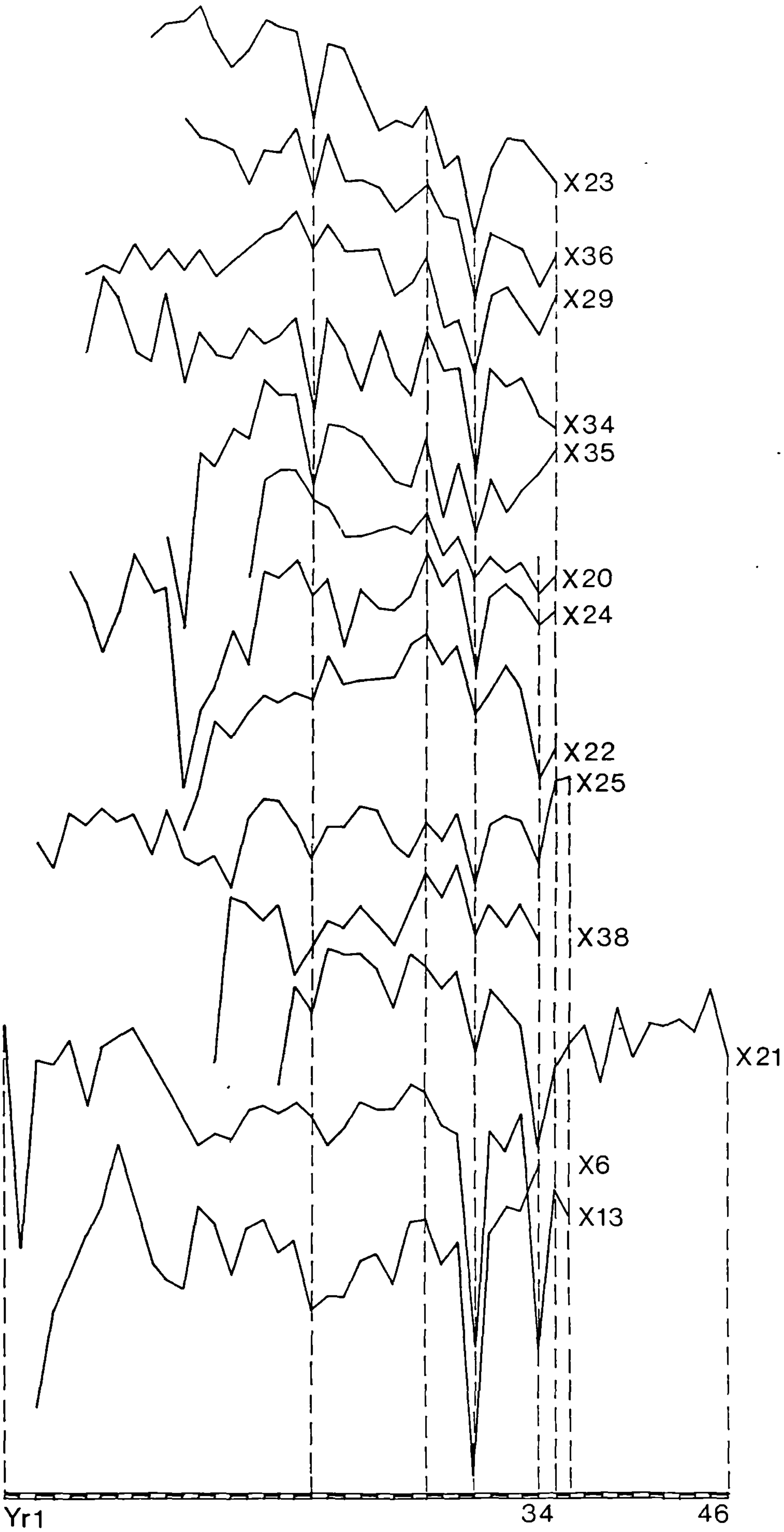


Fig.59 Oakbank alder; Block 17

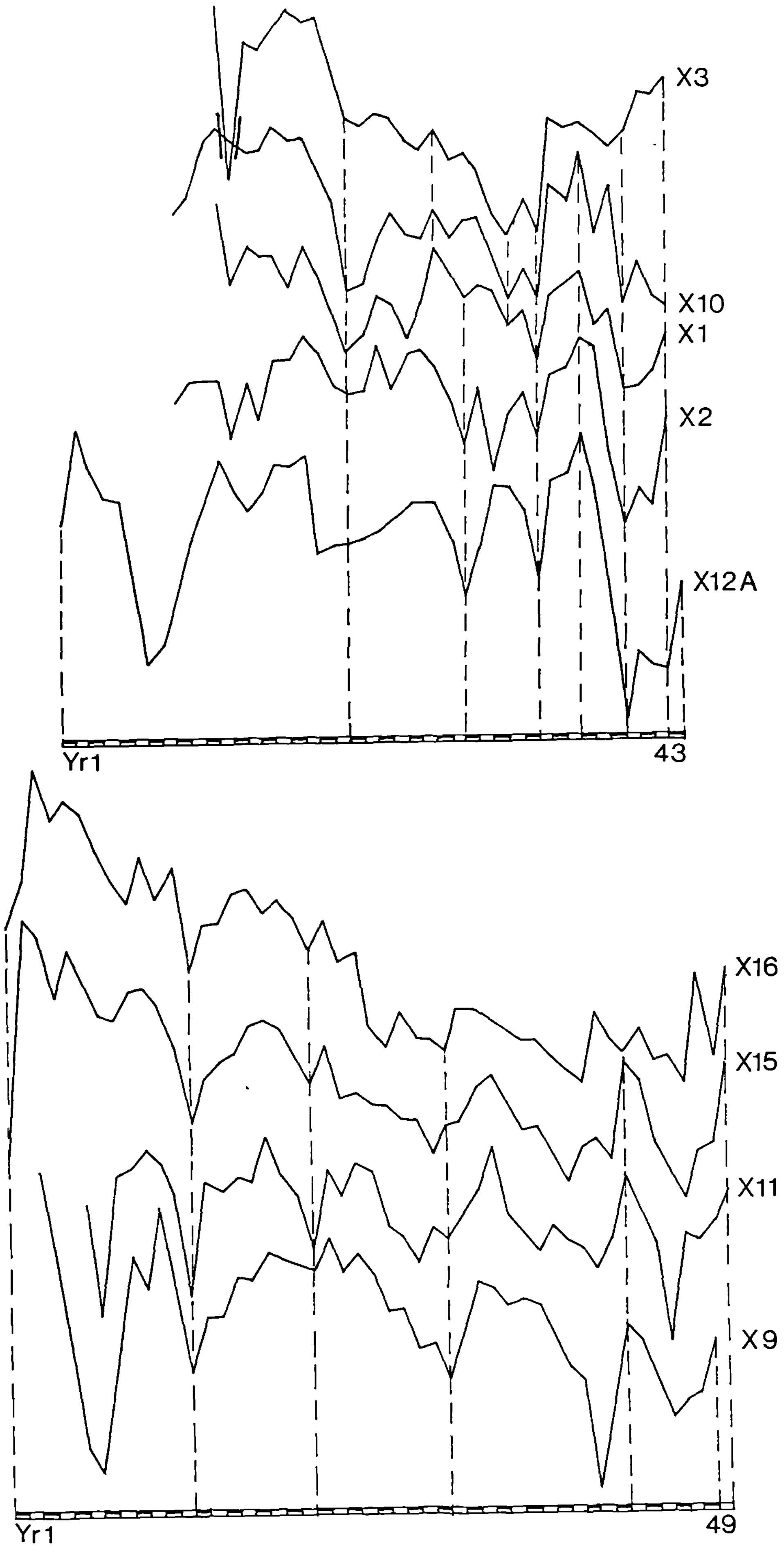


Fig.60 Oakbank alder; Blocks 18 and 19

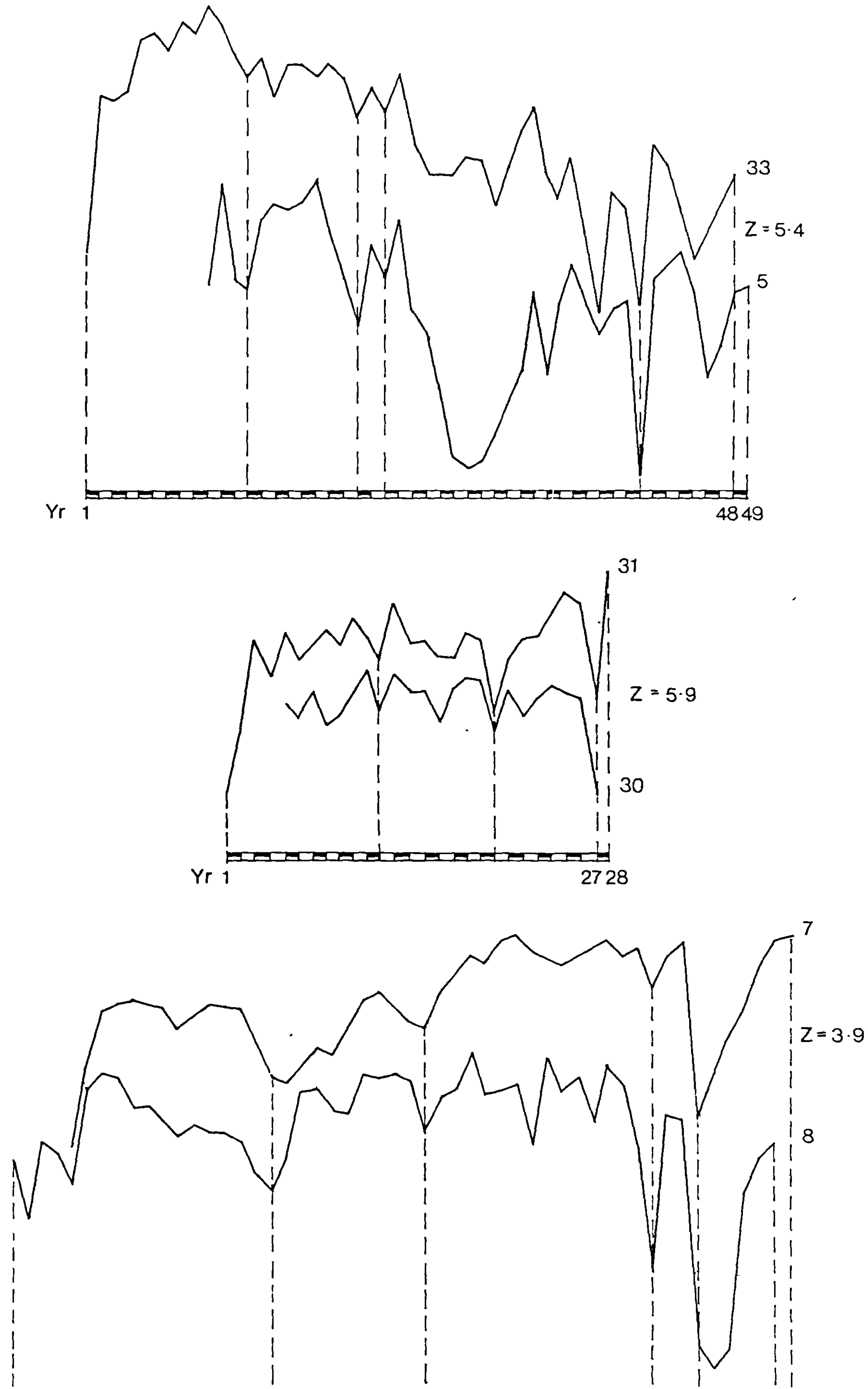


Fig.61 Oakbank alder; Blocks 20, 21 and 22

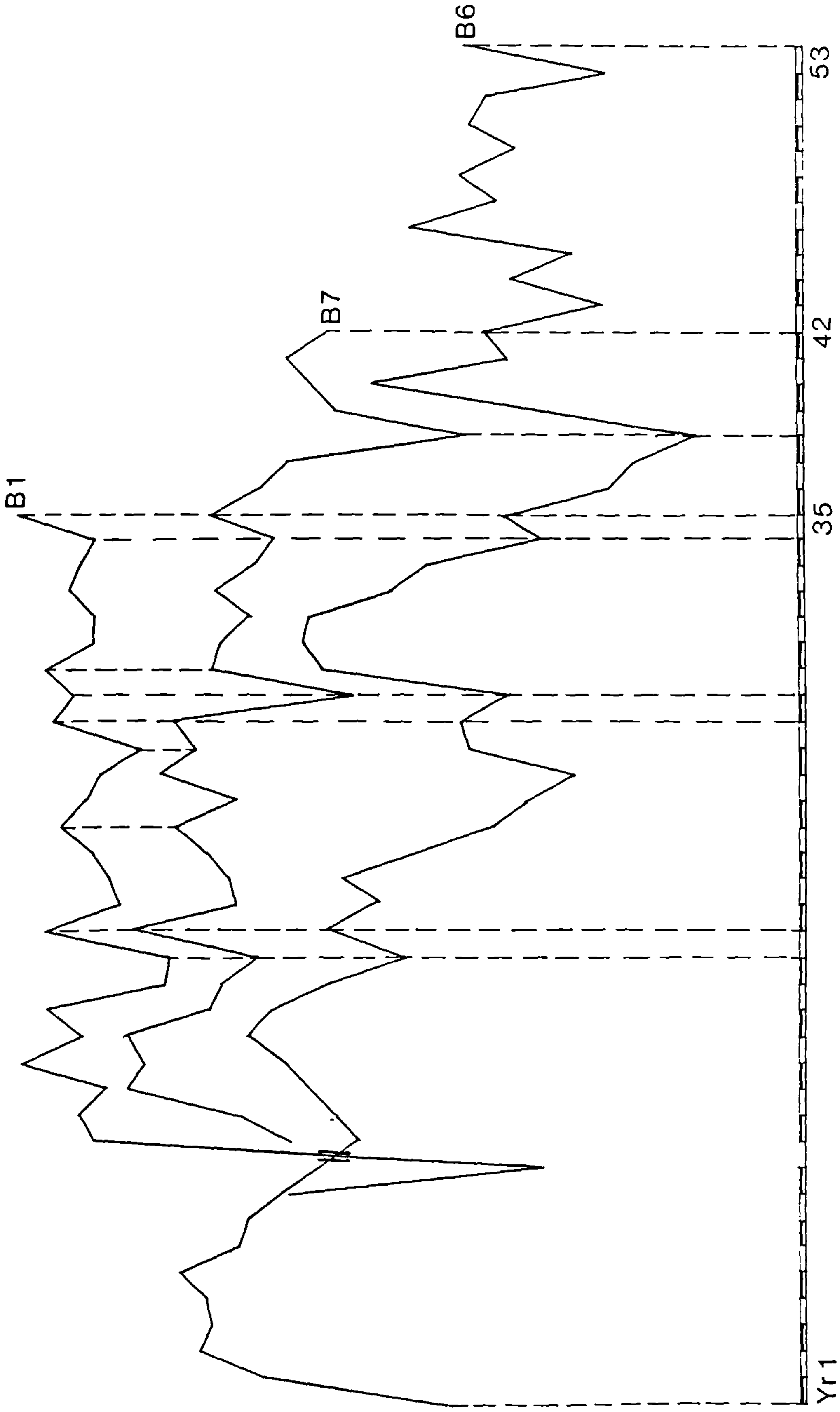


Fig.62

Oakbank alder; correlation between Block masters 1,6 and 7

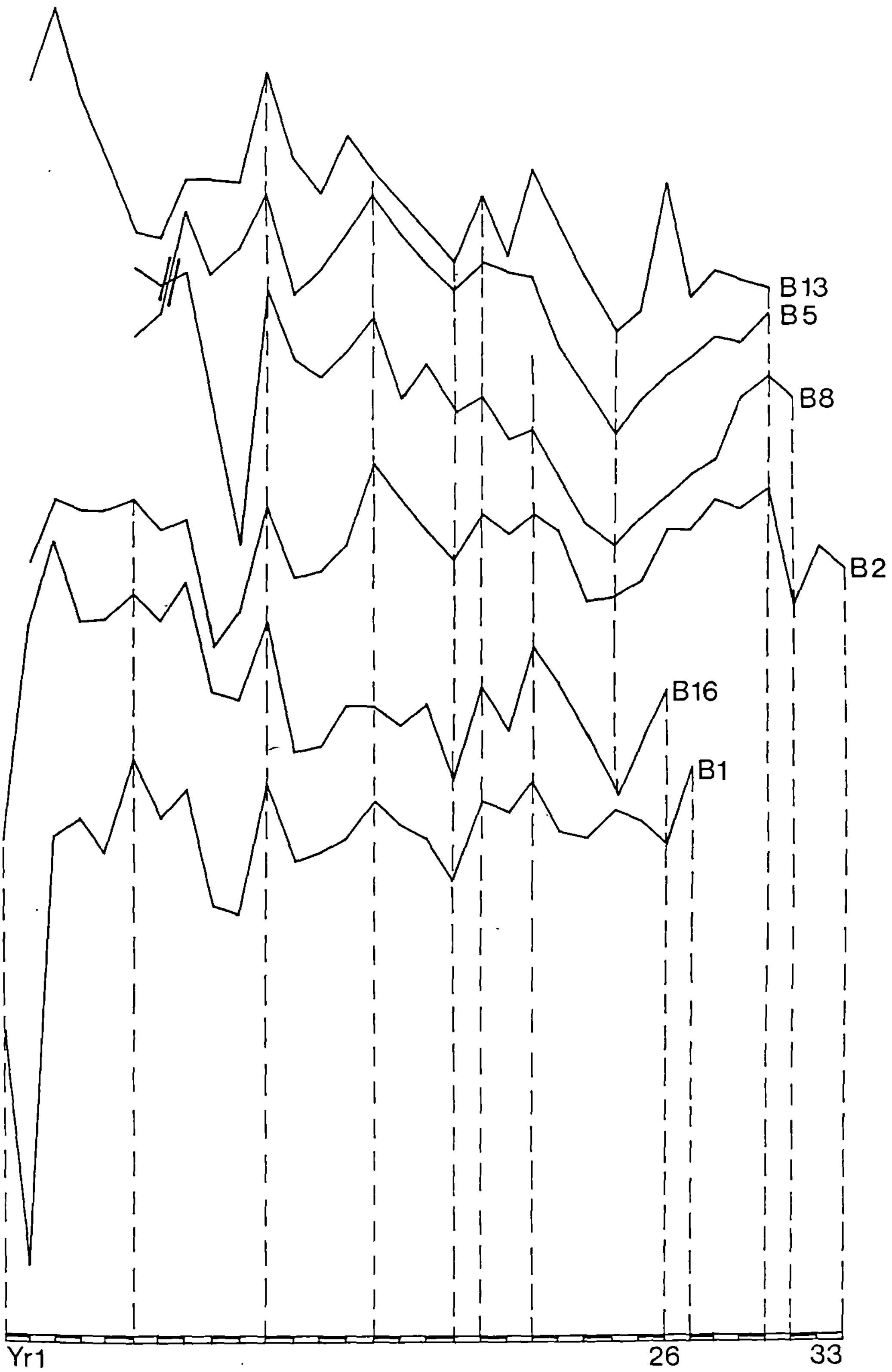


Fig.63

Oakbank alder; correlation between Block masters 1, 2, 5, 8, 13 and 16

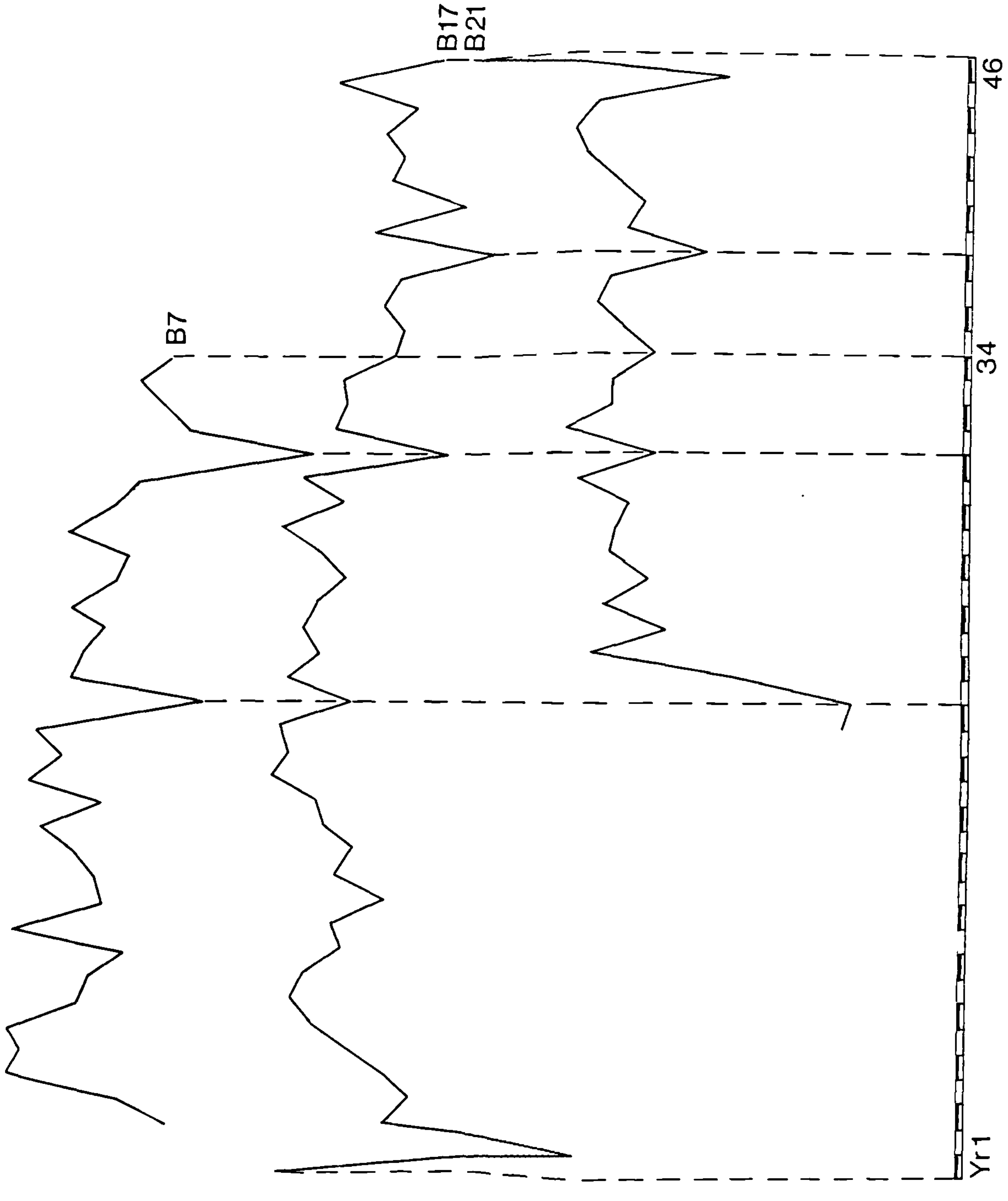


Fig.64

Oakbank alder; correlation between Block masters 7, 17 and 21

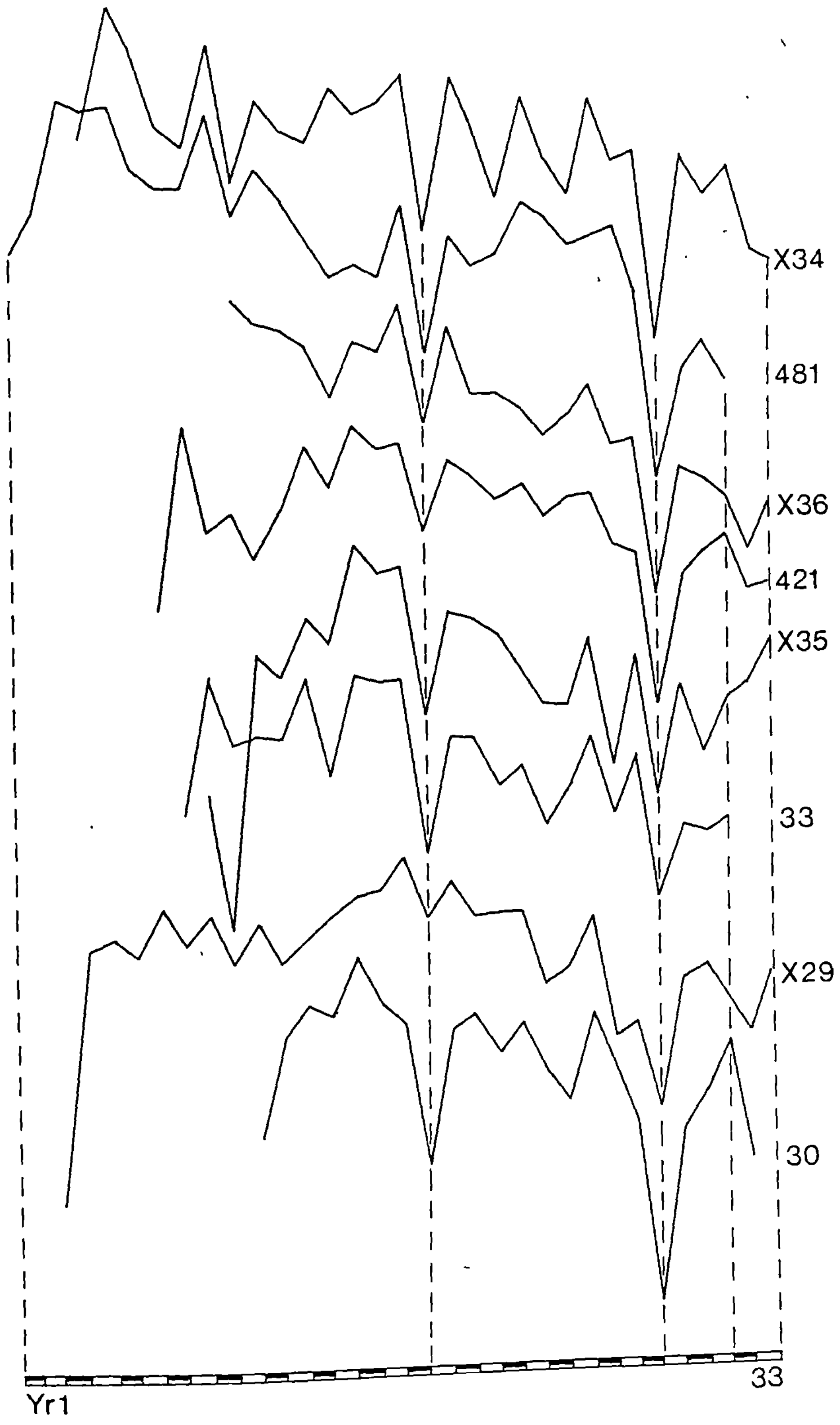


Fig.65

Oakbank alder; correlation between members of Blocks 7 and 17

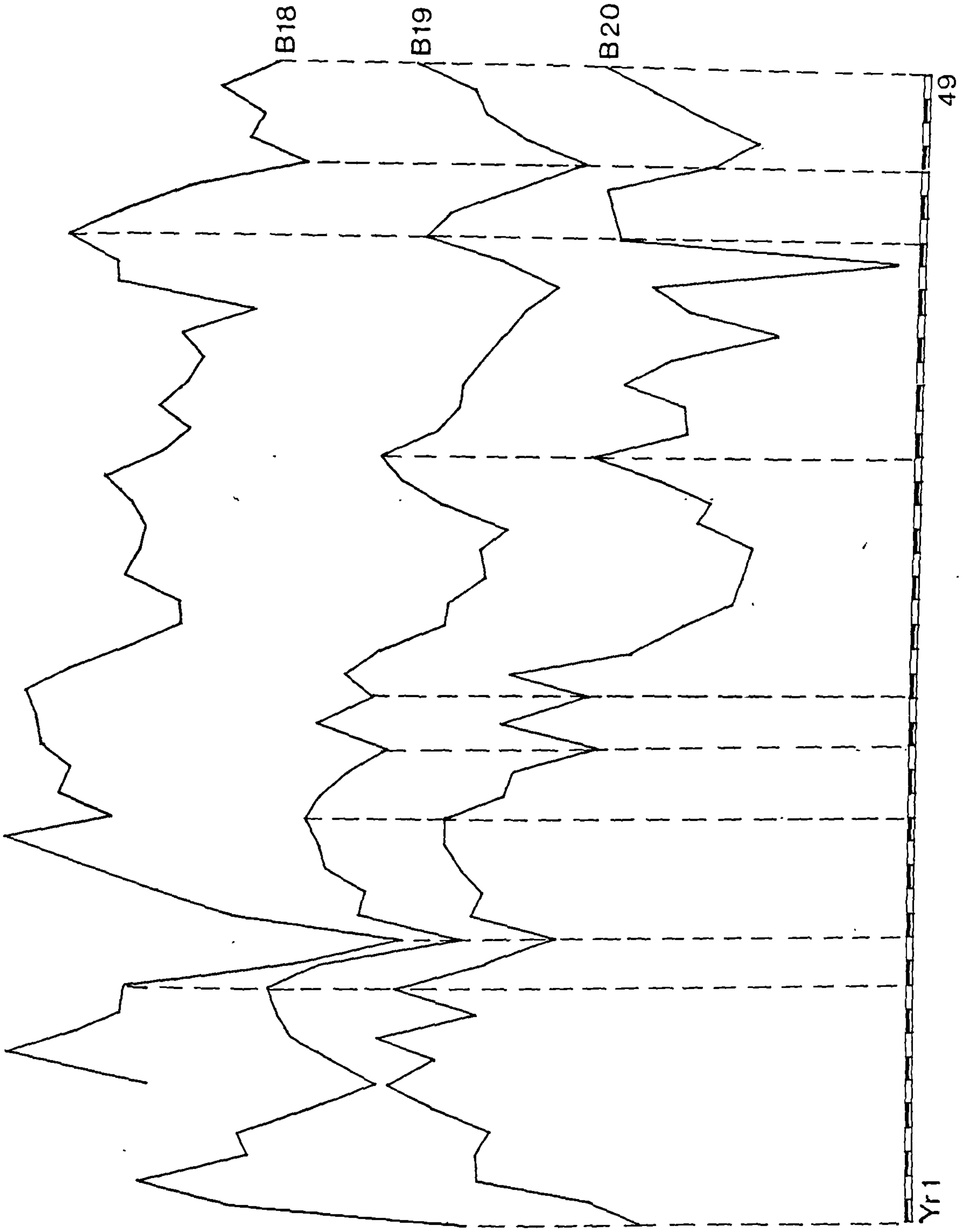


Fig.66

Oakbank alder; correlation between Block masters 18, 19 and 20

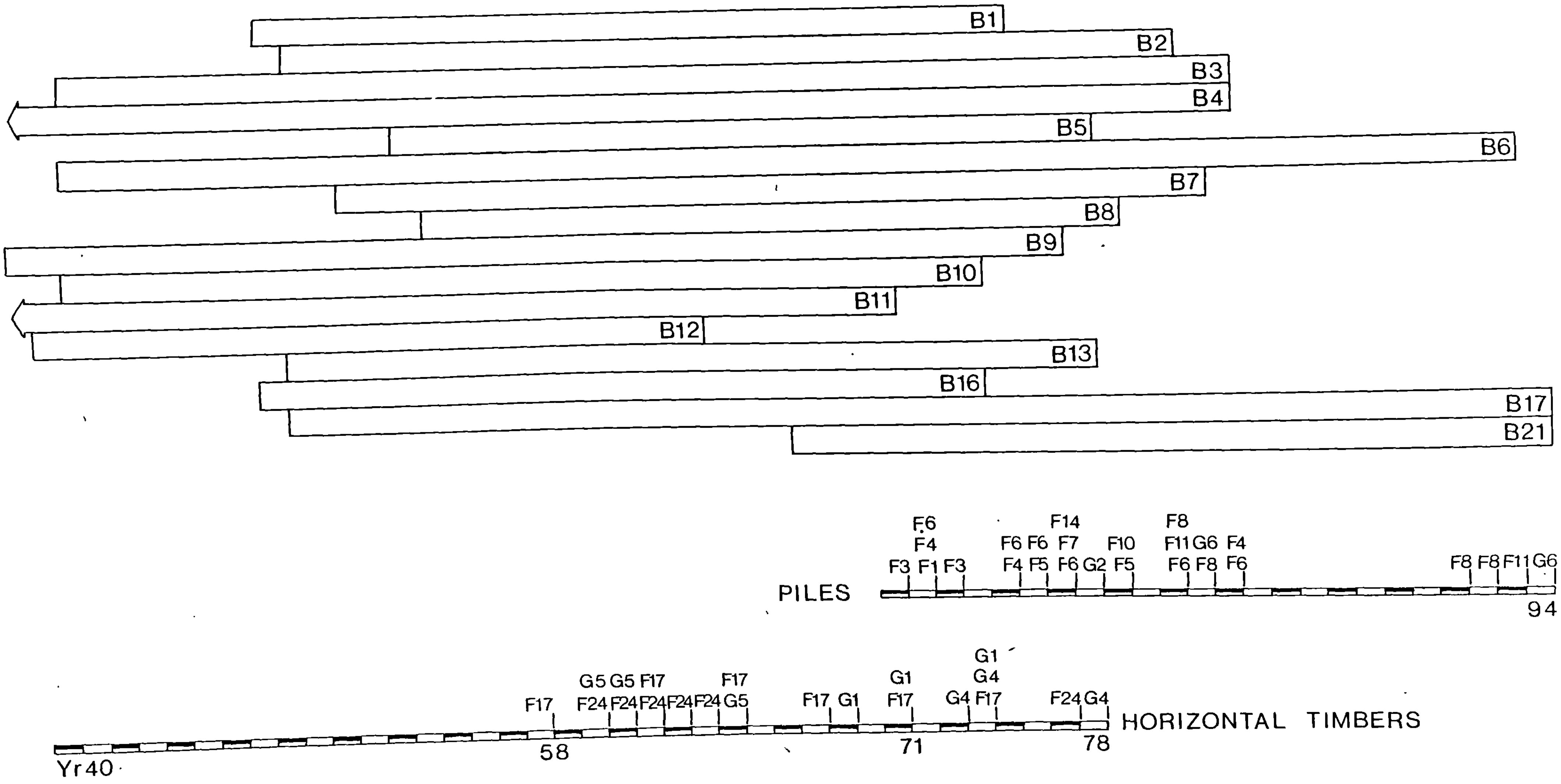


Fig.67 Oakbank alder; traditional site chronology

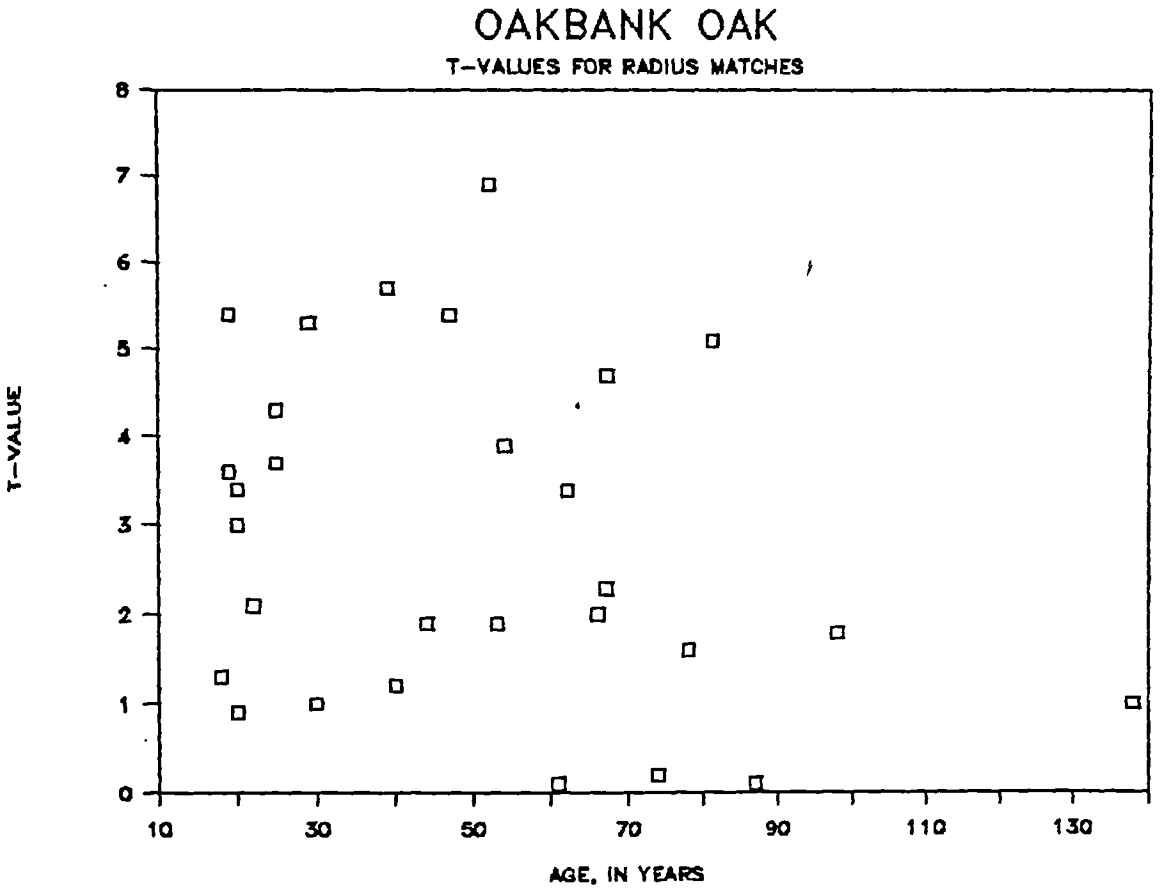


Fig.68 Oakbank oak; T-values and sequence length

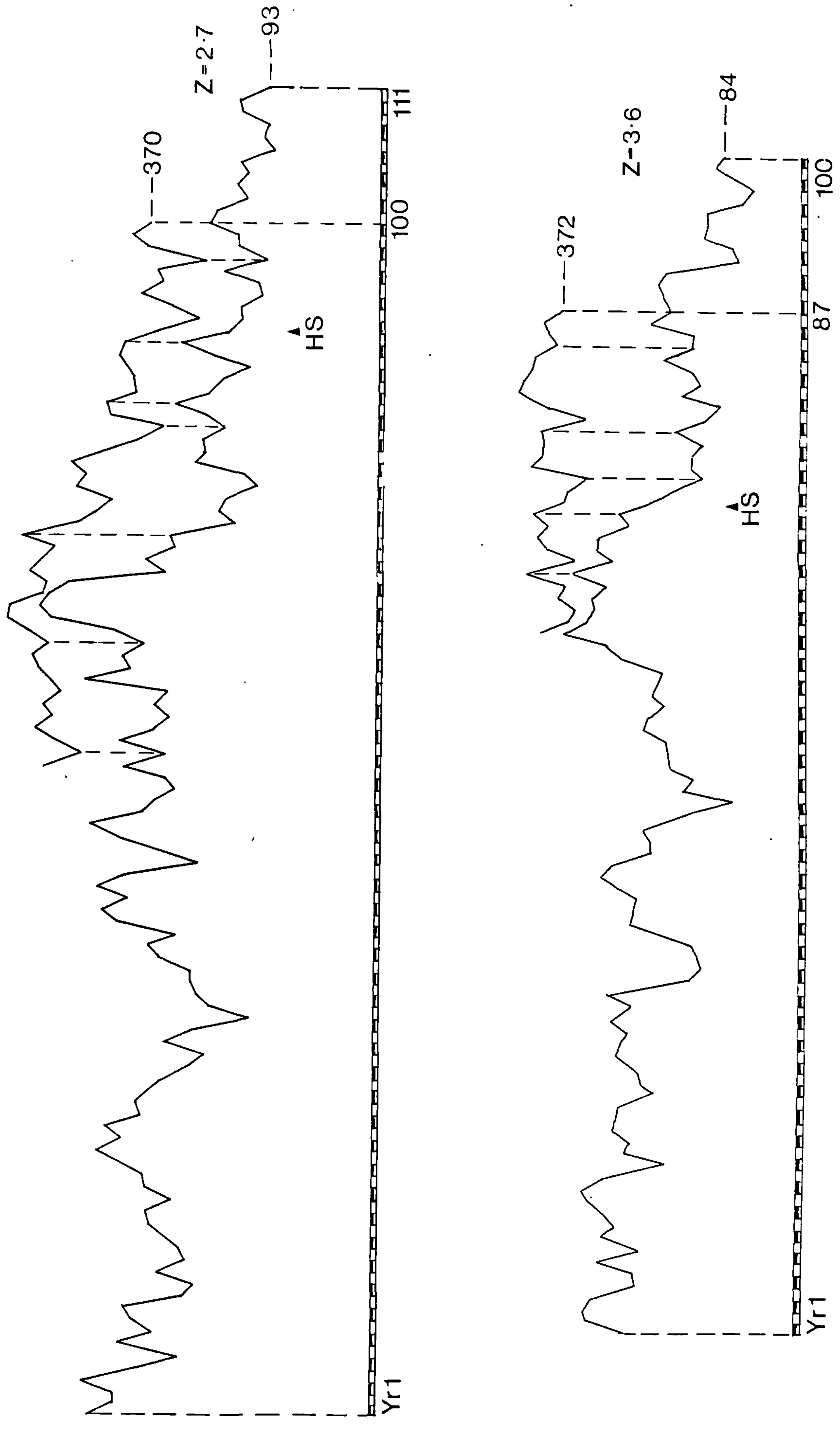


Fig.69 Oakbank oak; F16 correlations

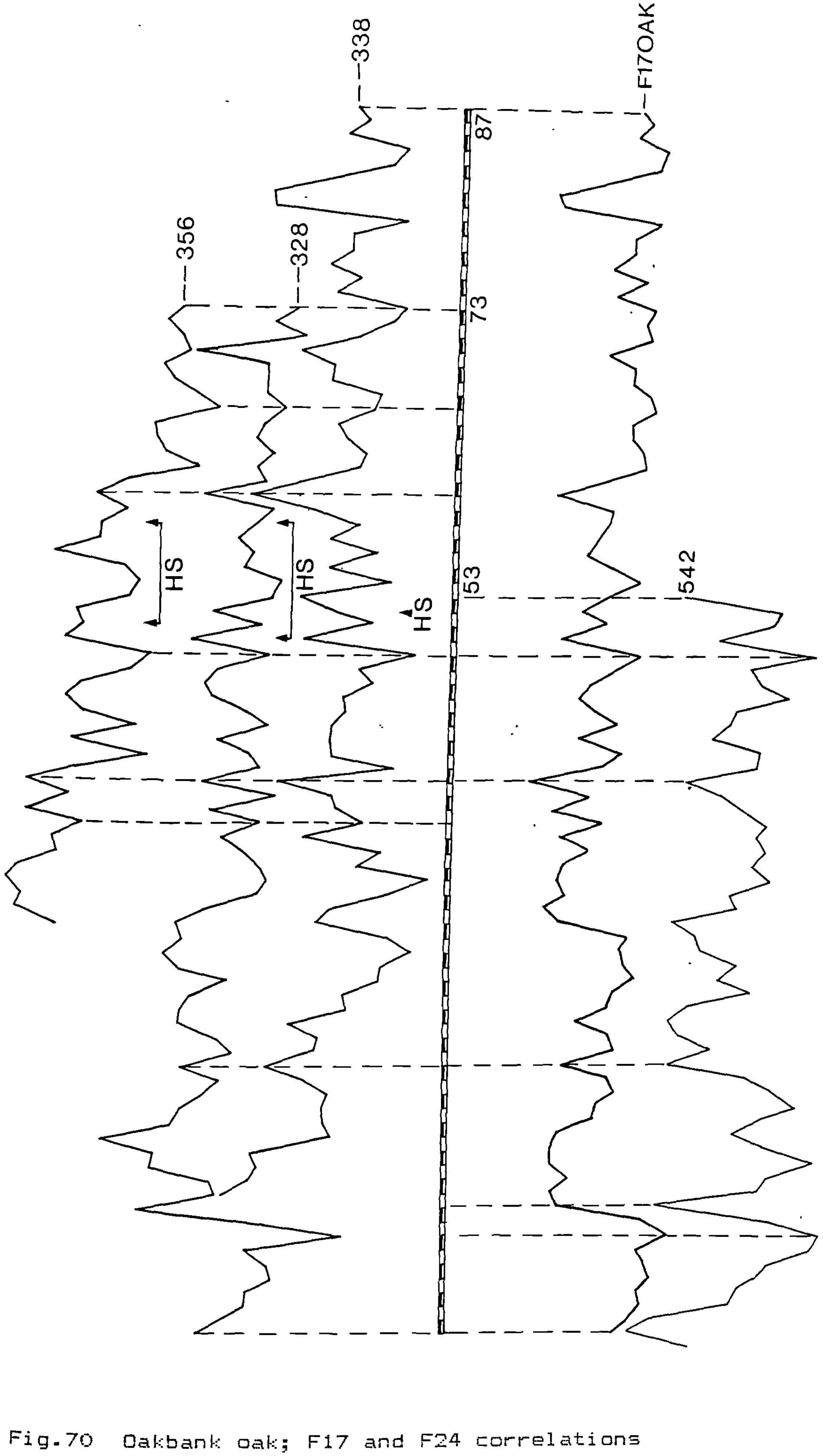


Fig.70 Oakbank oak; F17 and F24 correlations

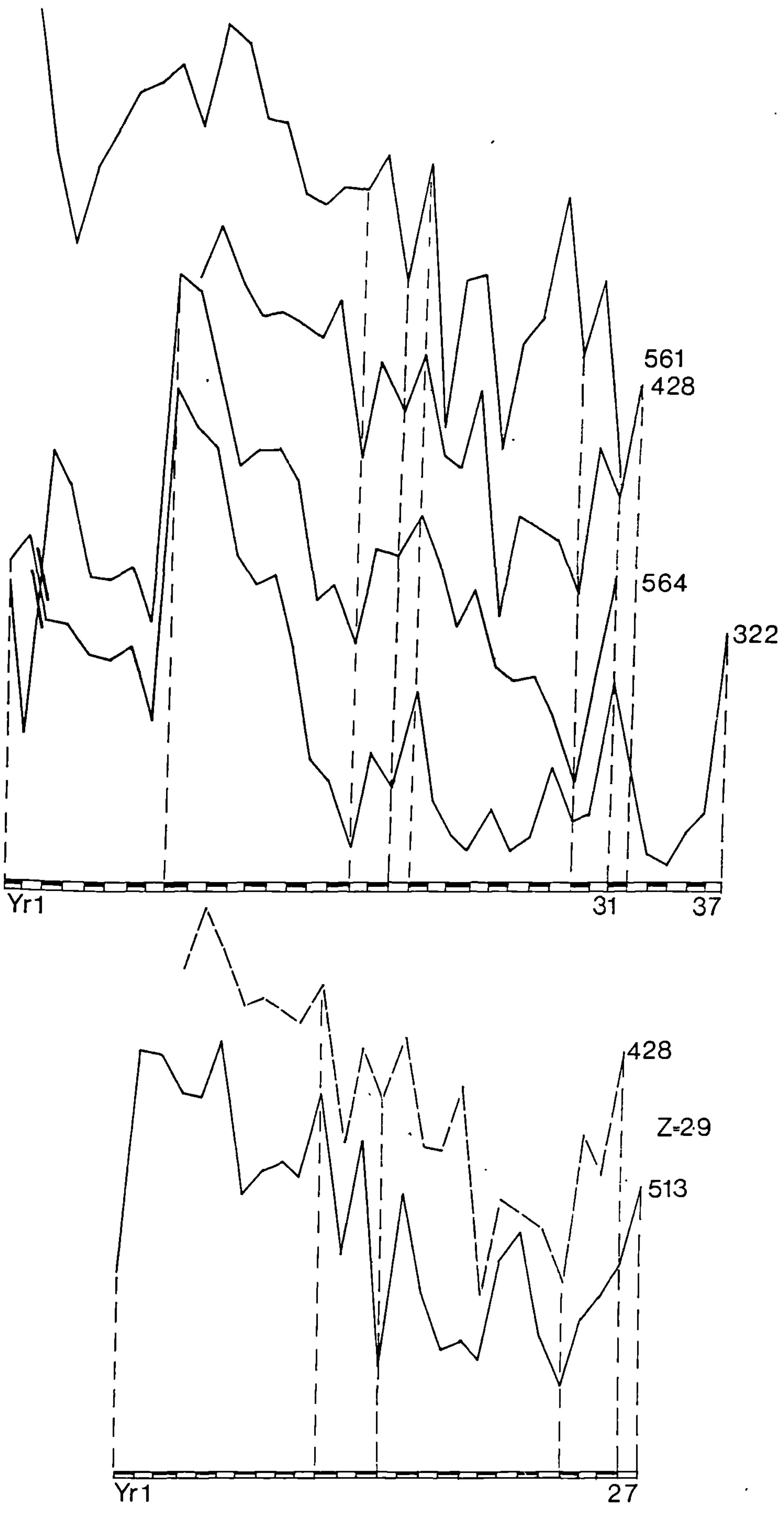


Fig.71 Oakbank hazel; correlations

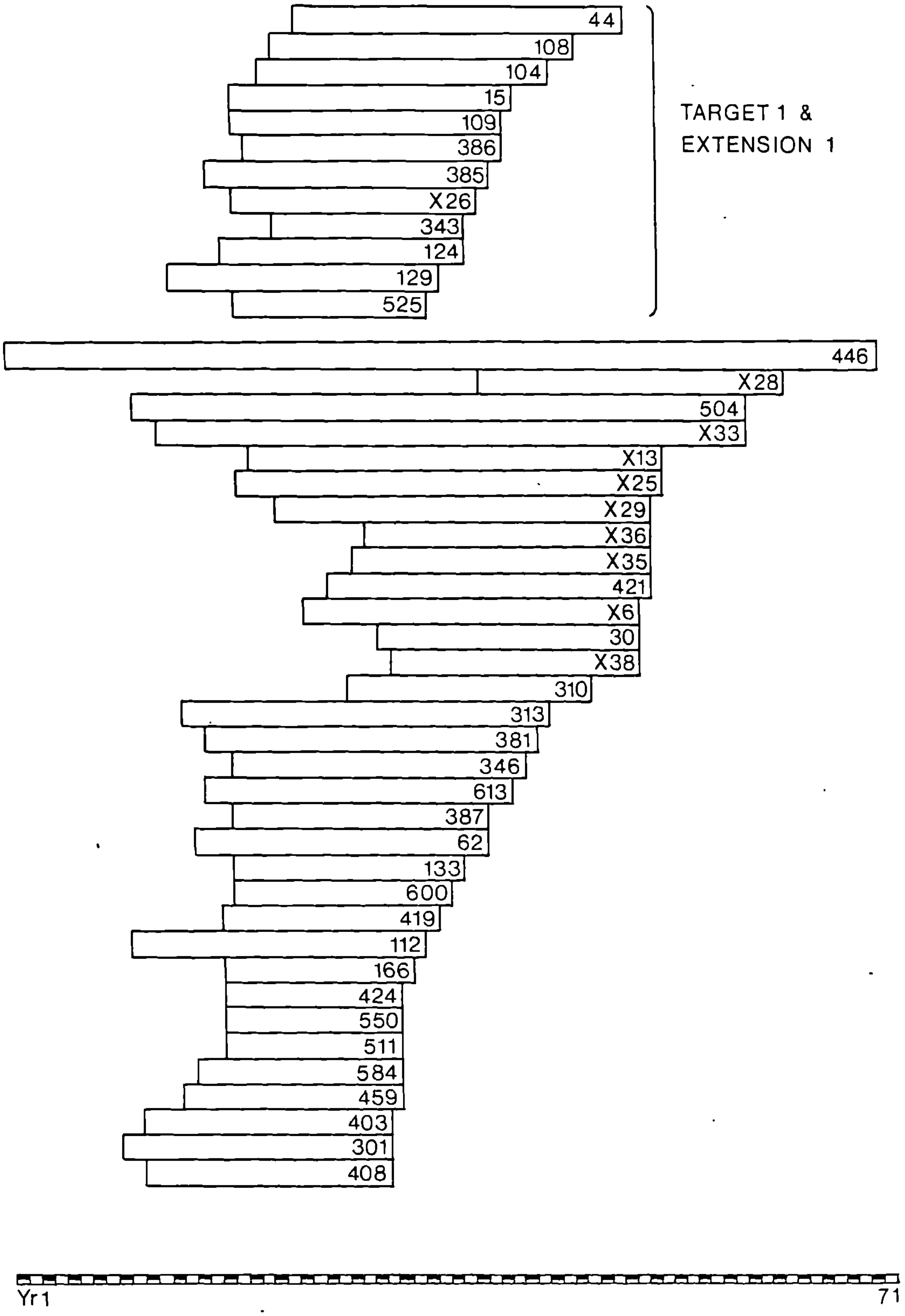


Fig.72 Oakbank alder; Target 1, block diagram

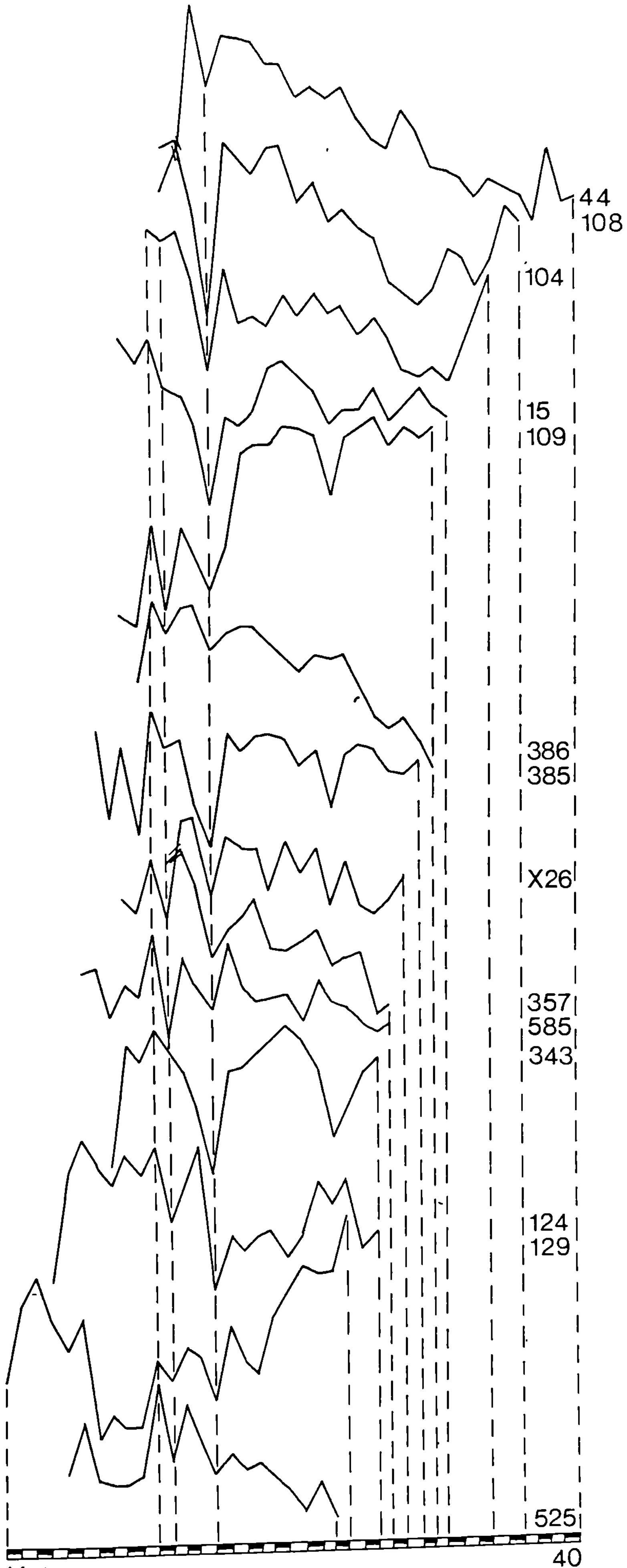


Fig.73 Oakbank alder; Target 1, visual correlations

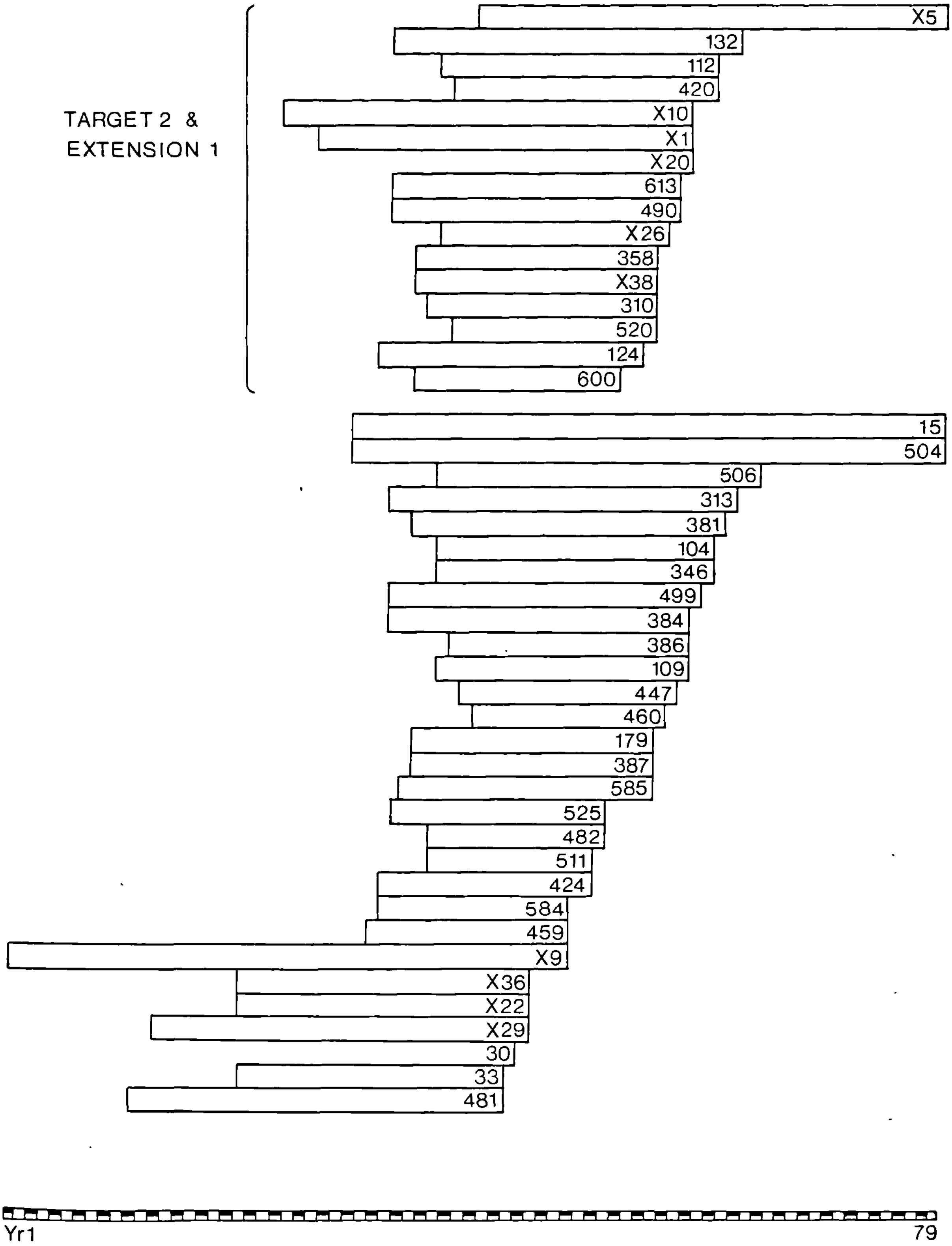


Fig.74 Oakbank alder; Target 2, block diagram

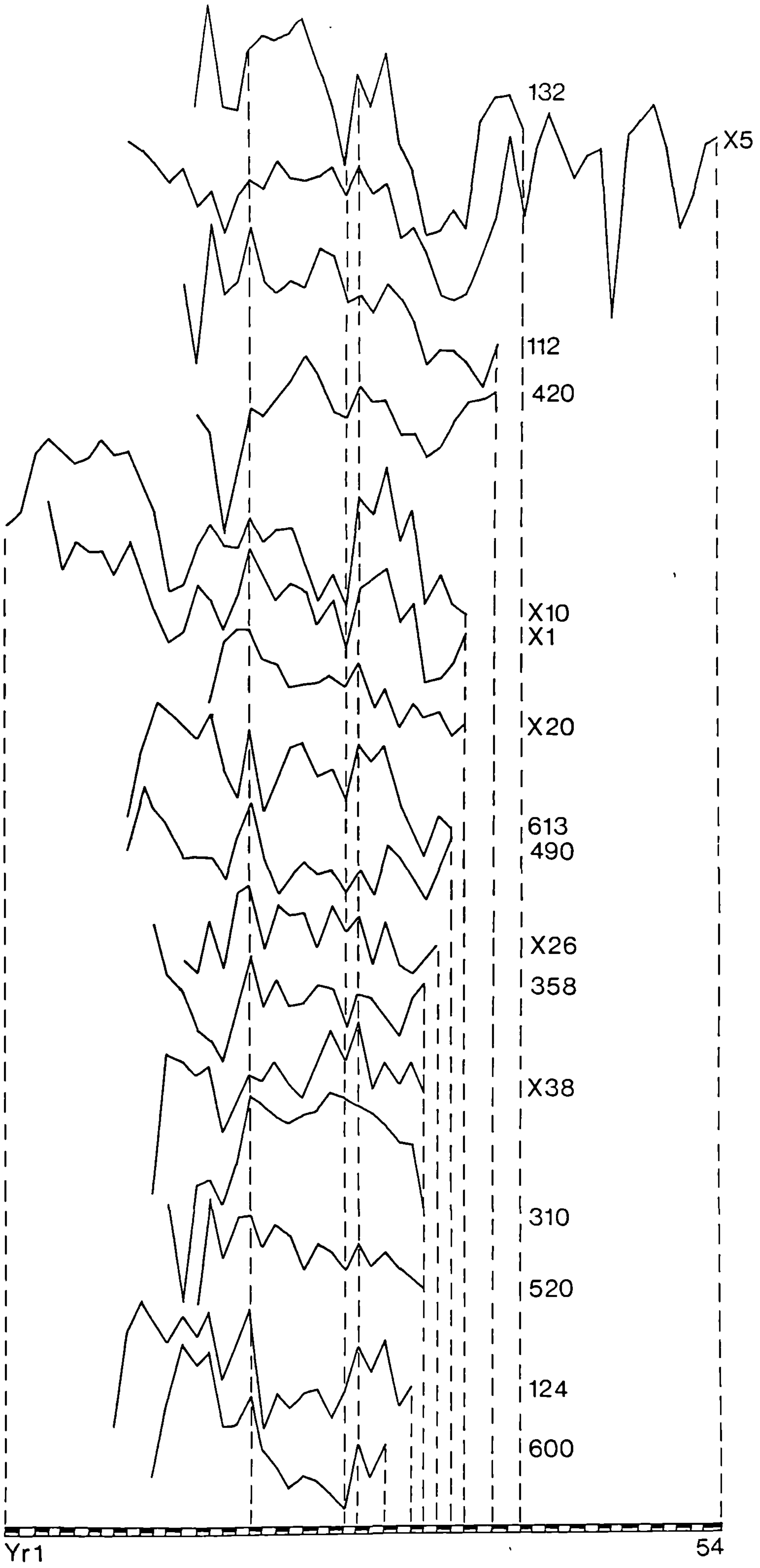


Fig.75 Oakbank alder; Target 2, visual correlations

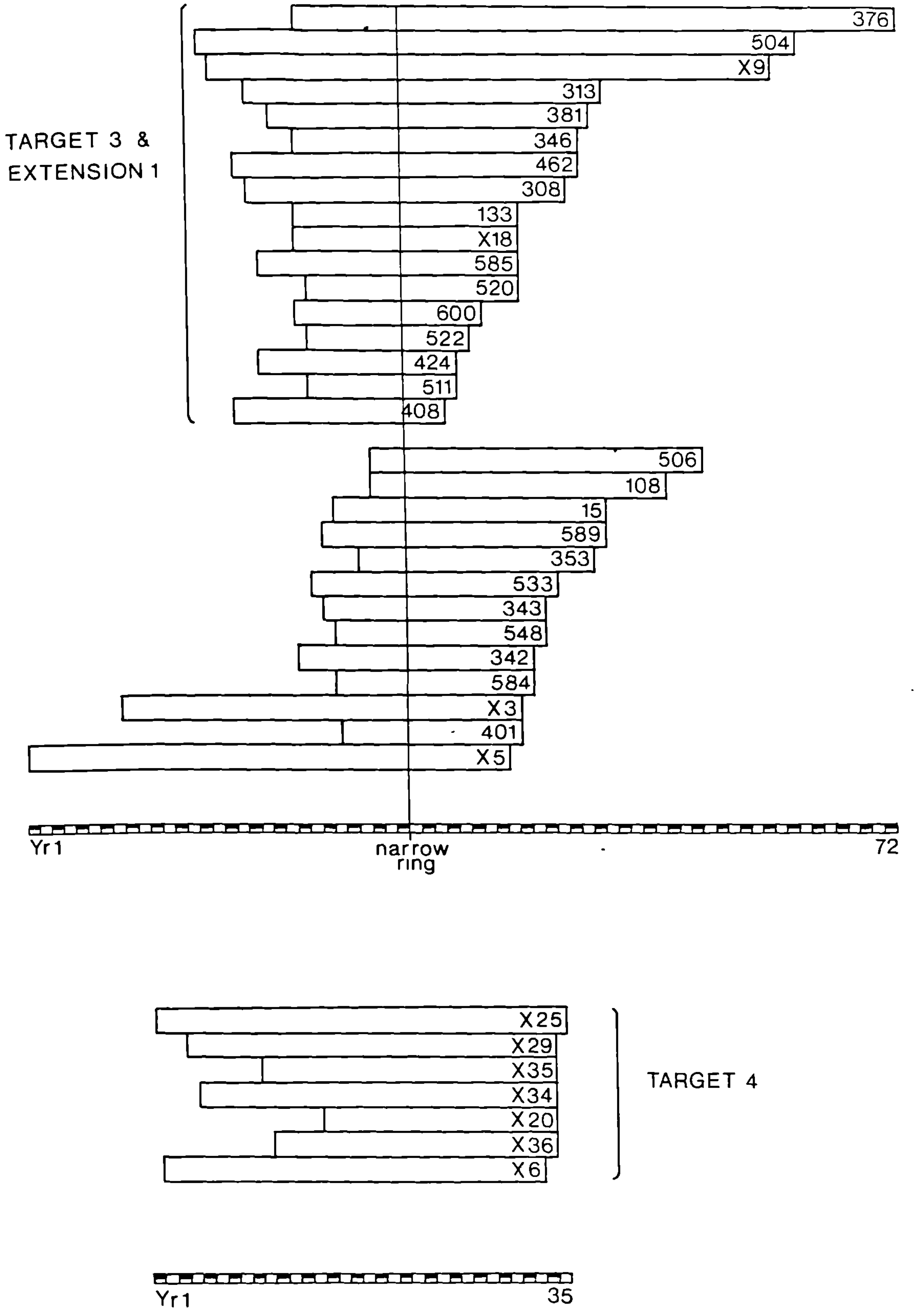


Fig.76 Oakbank alder; Targets 3 and 4, block diagrams

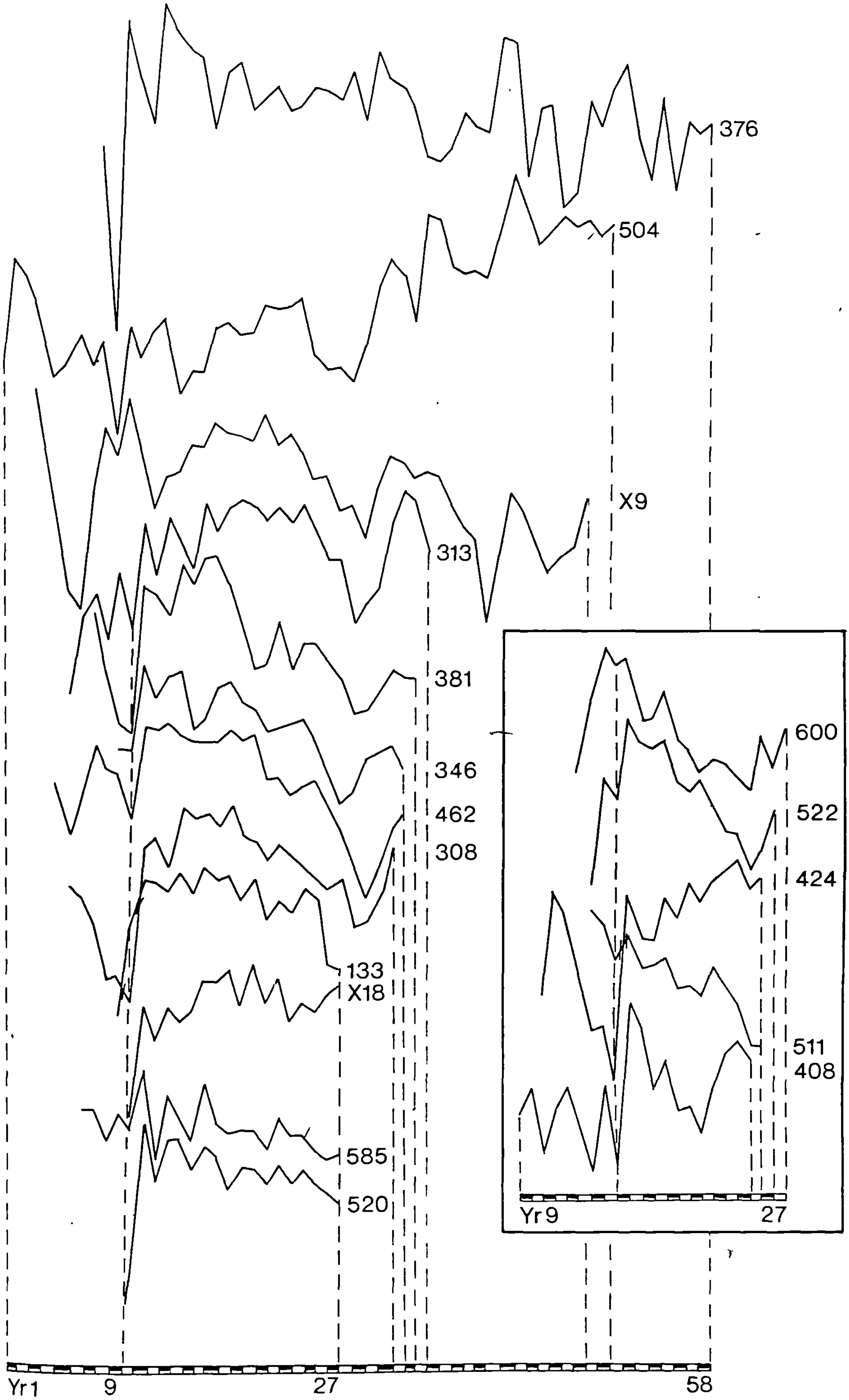


Fig.77 Corban. alcon; Target 3, visual correlations

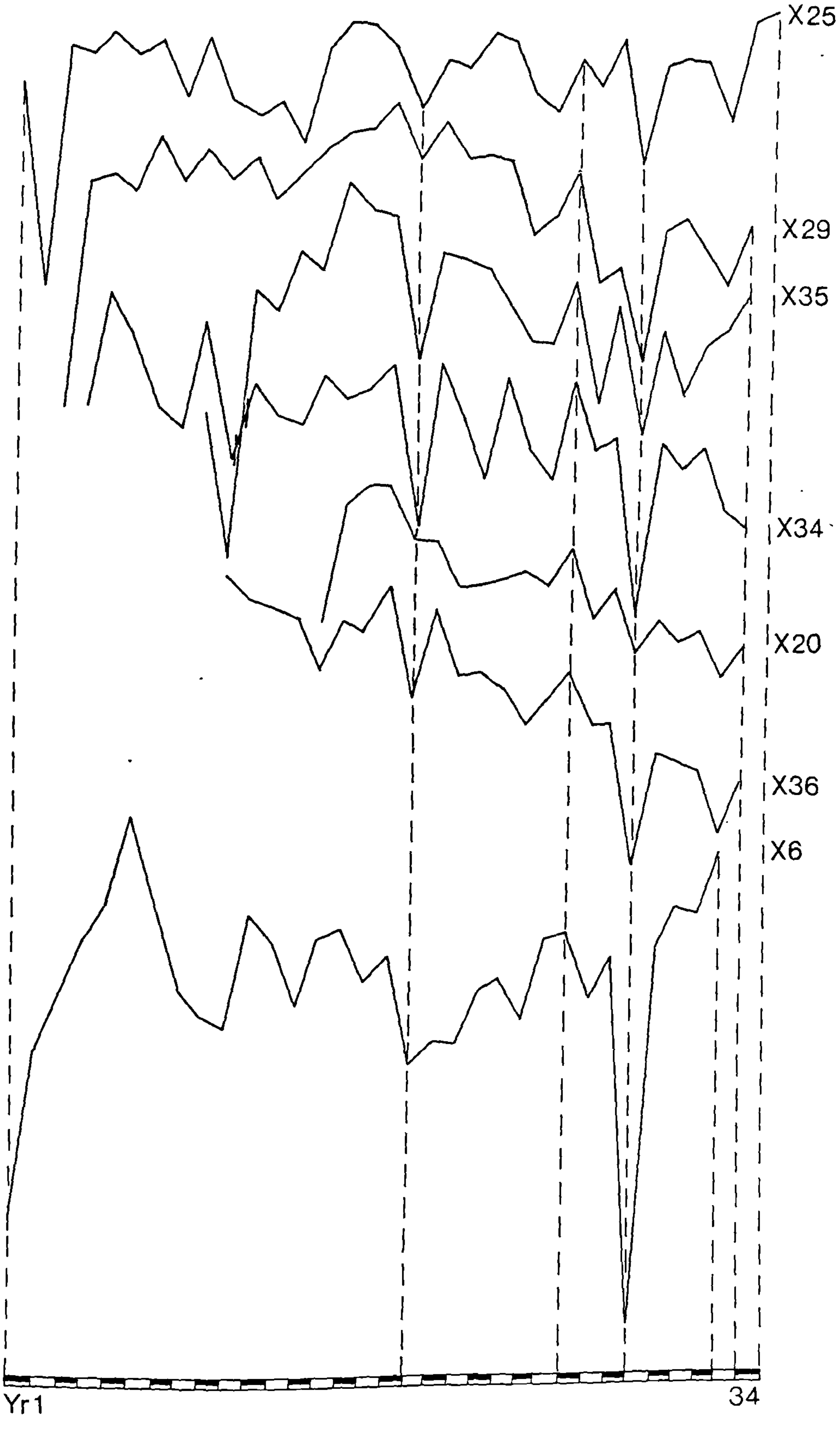


Fig.78 Oakbank alder; Target 4, visual correlations

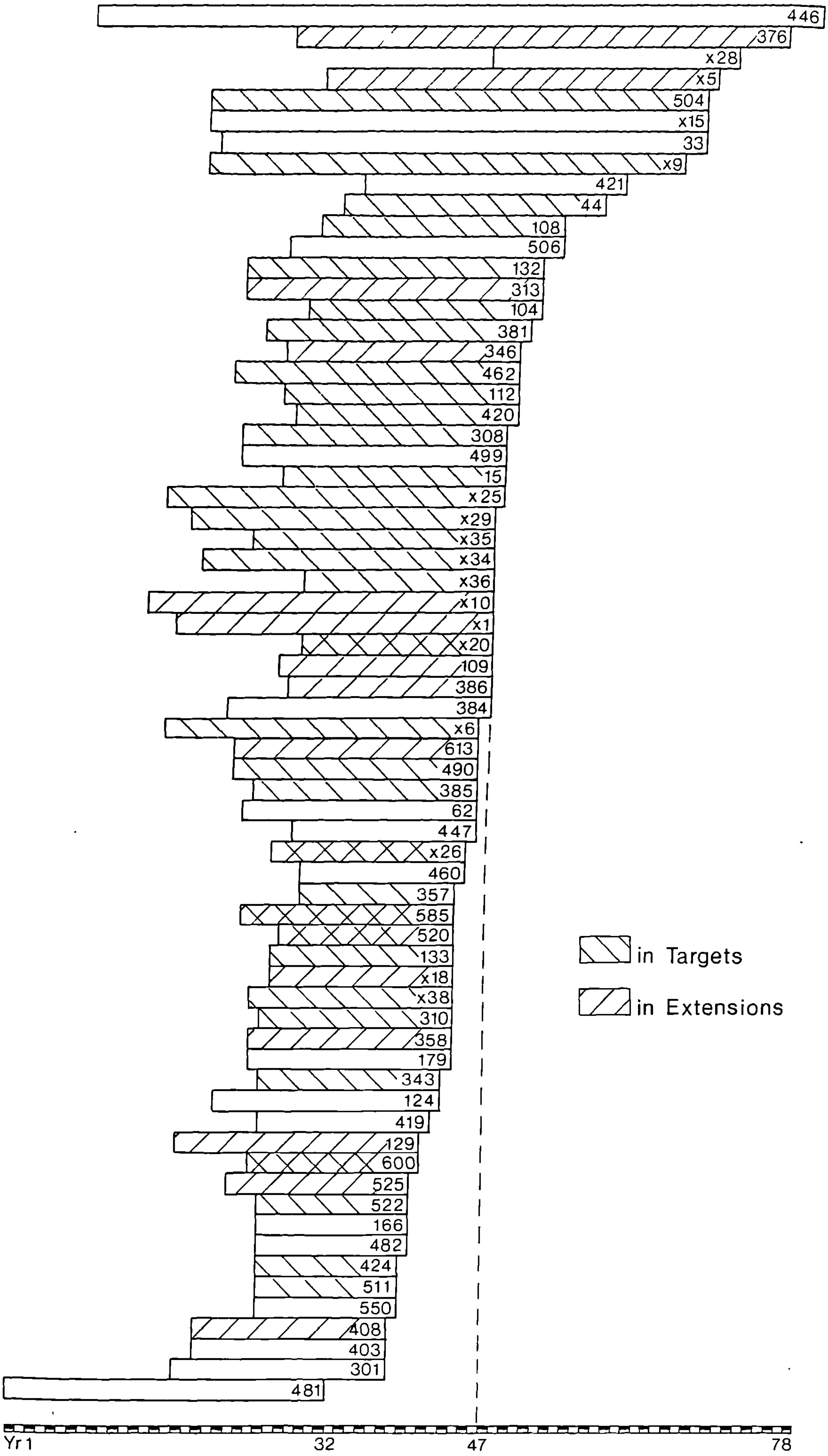


Fig.79 Oakbank alder; the SORT.STRING site chronology

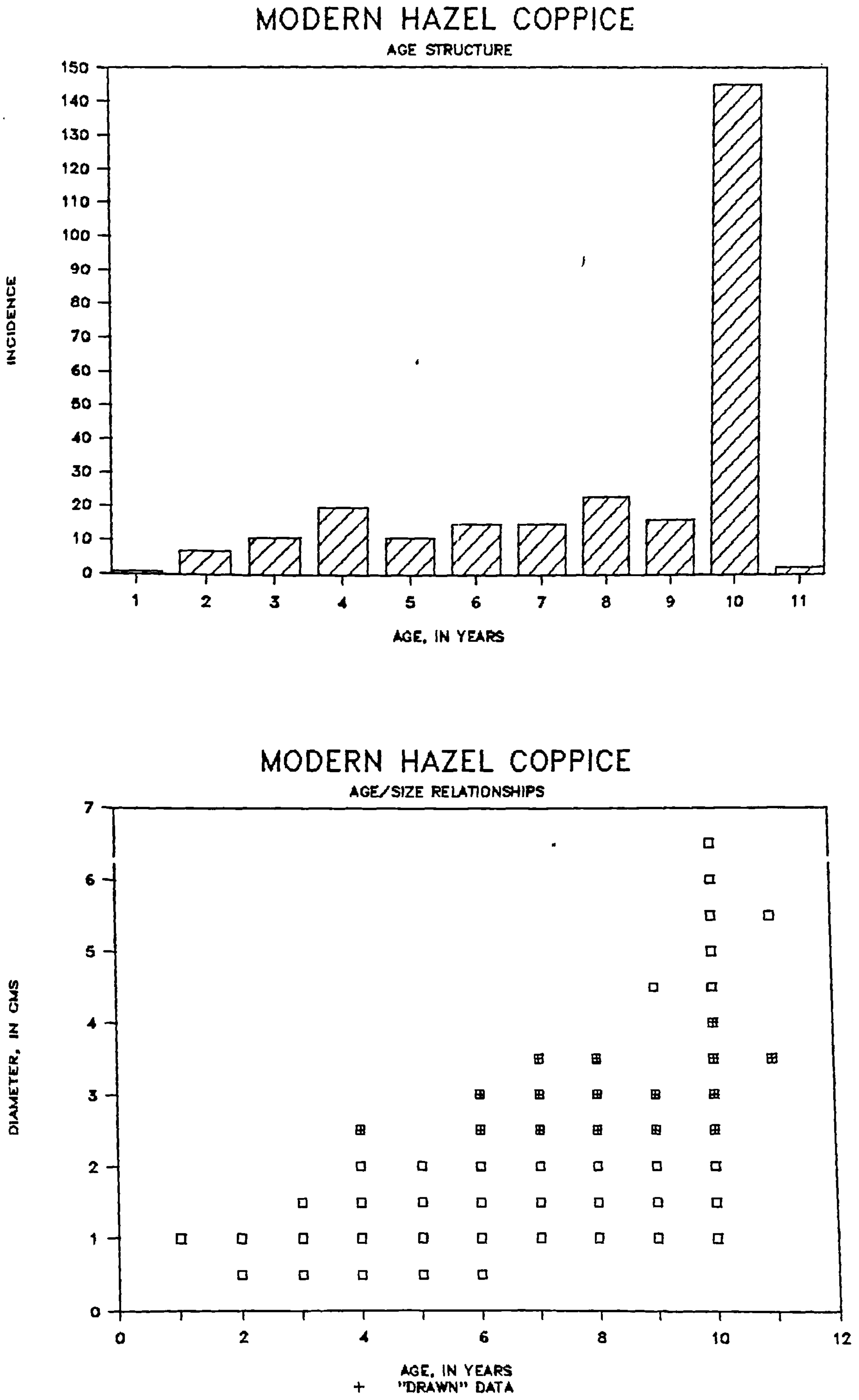
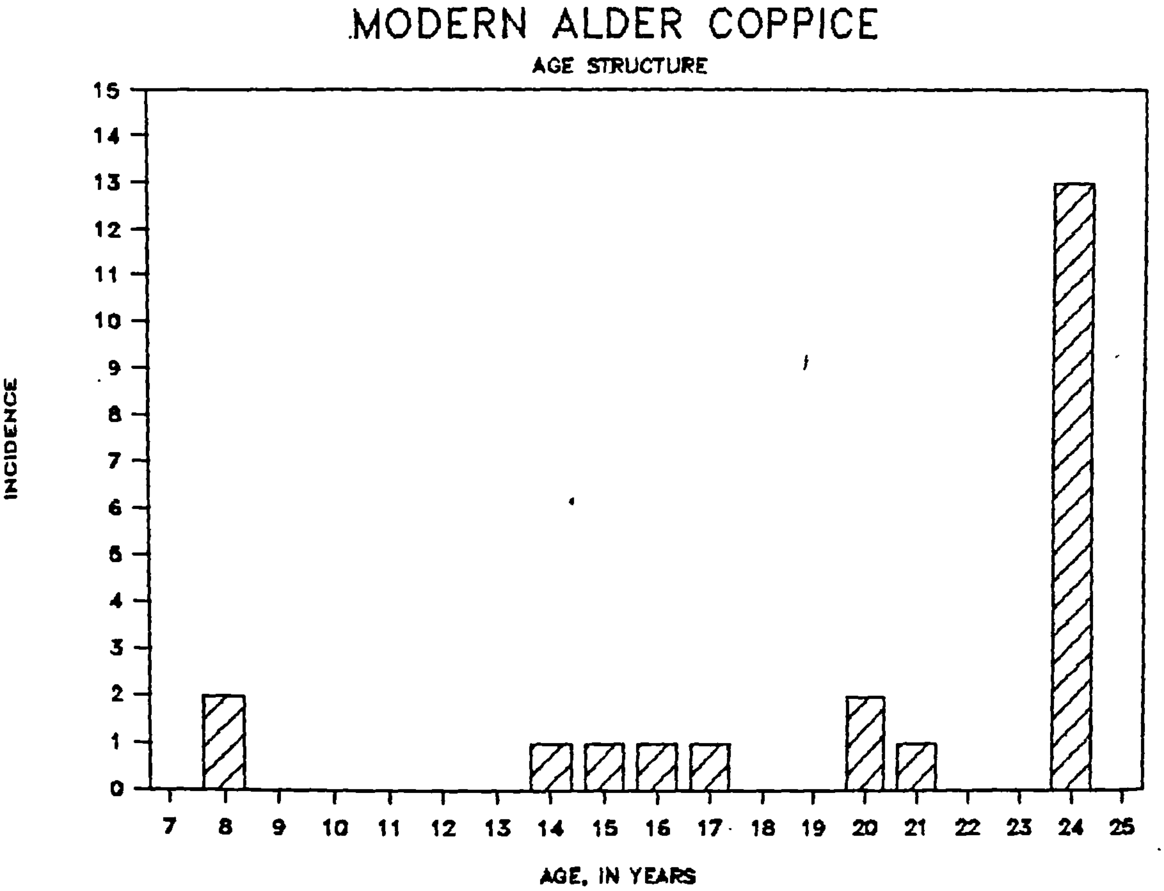


Fig.80 Modern Hazel Coppice; age/size relationships and age structure



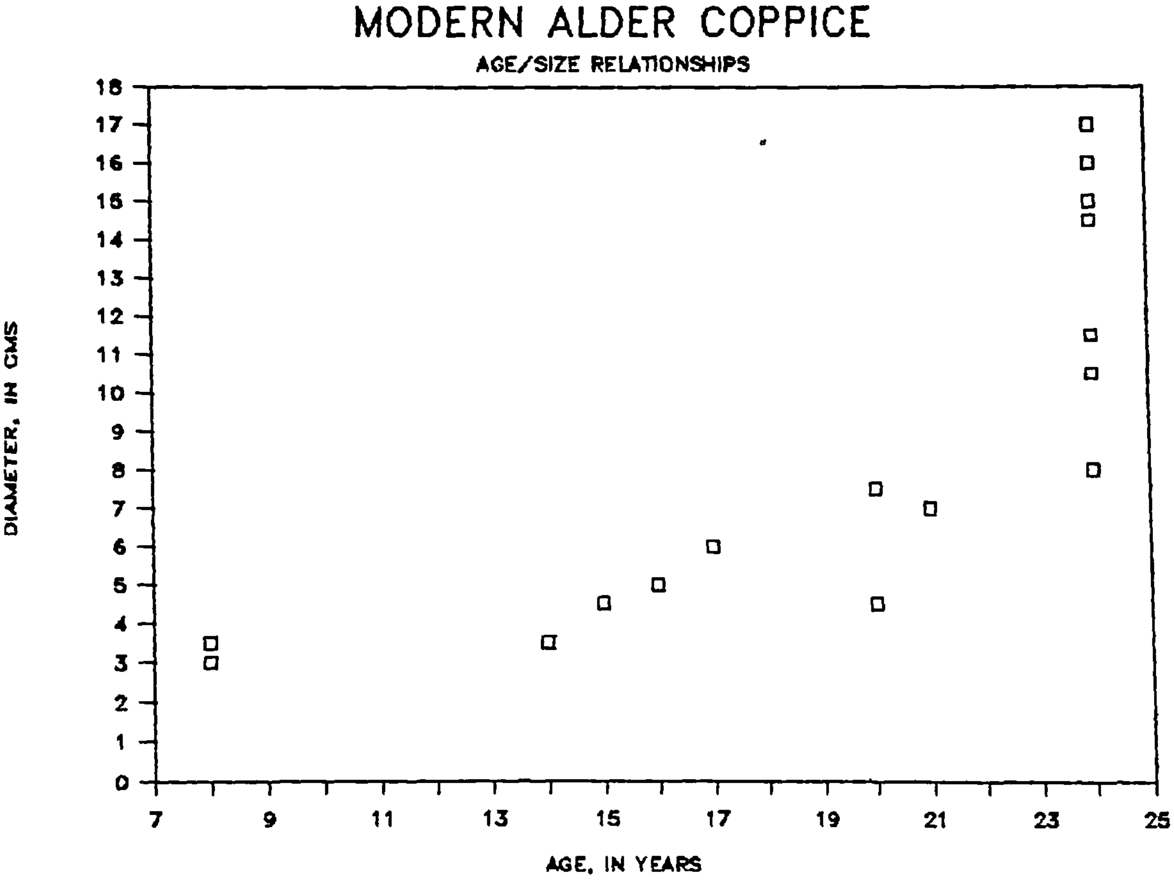
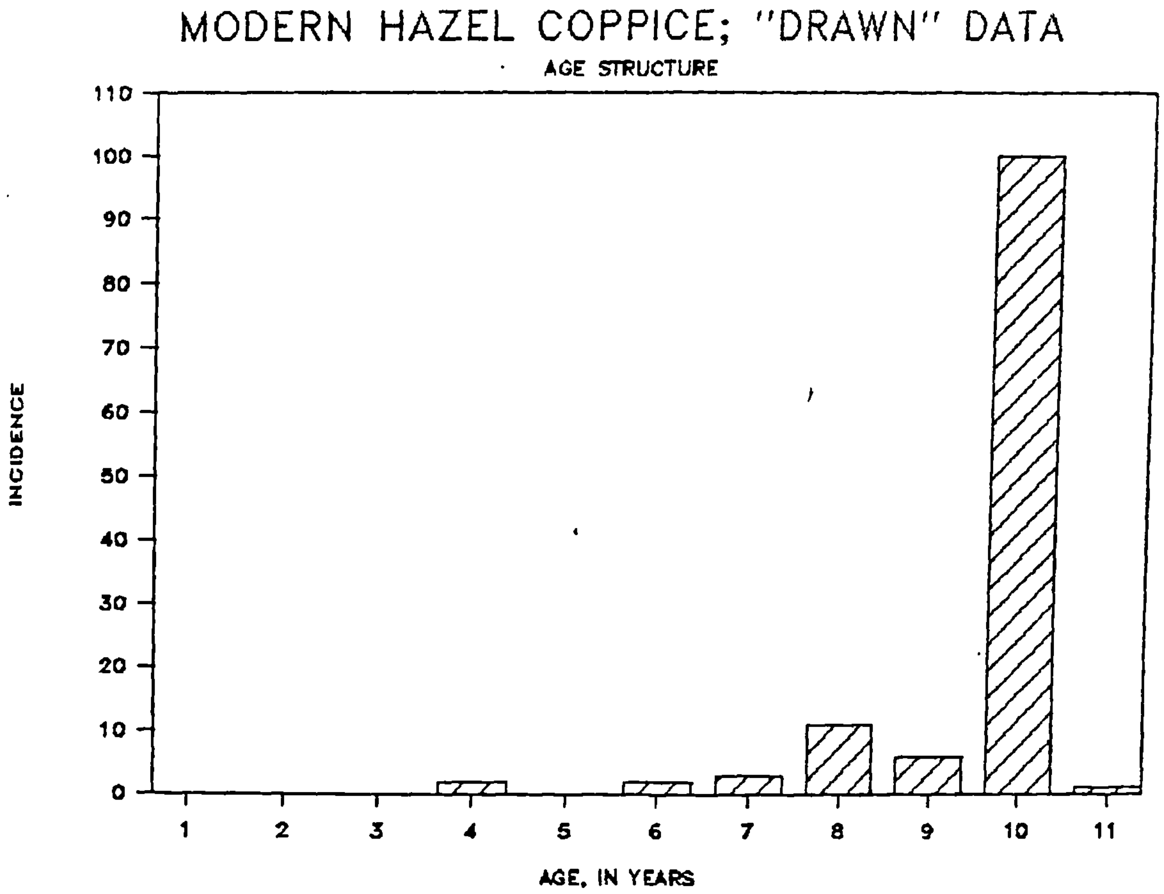


Fig.81 Modern Alder Coppice; age/size relationships and age structure



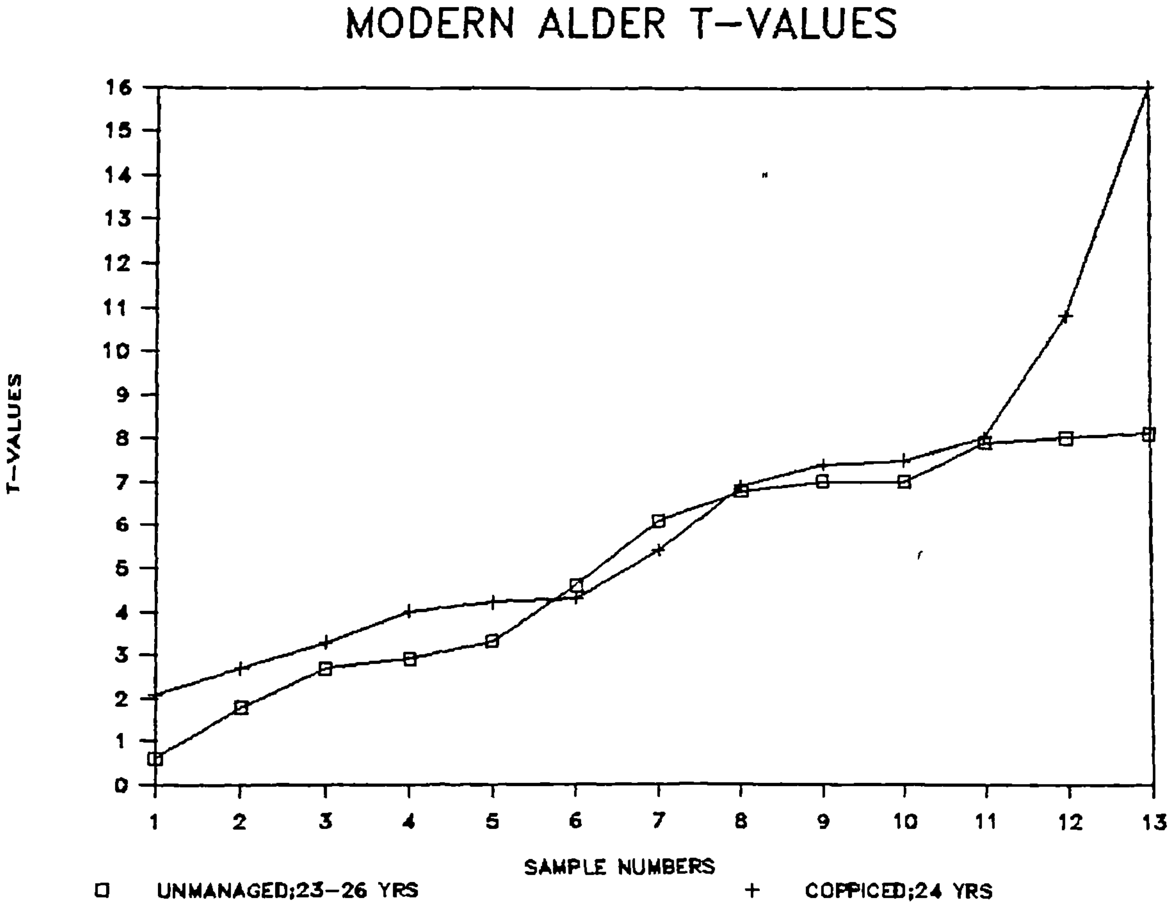
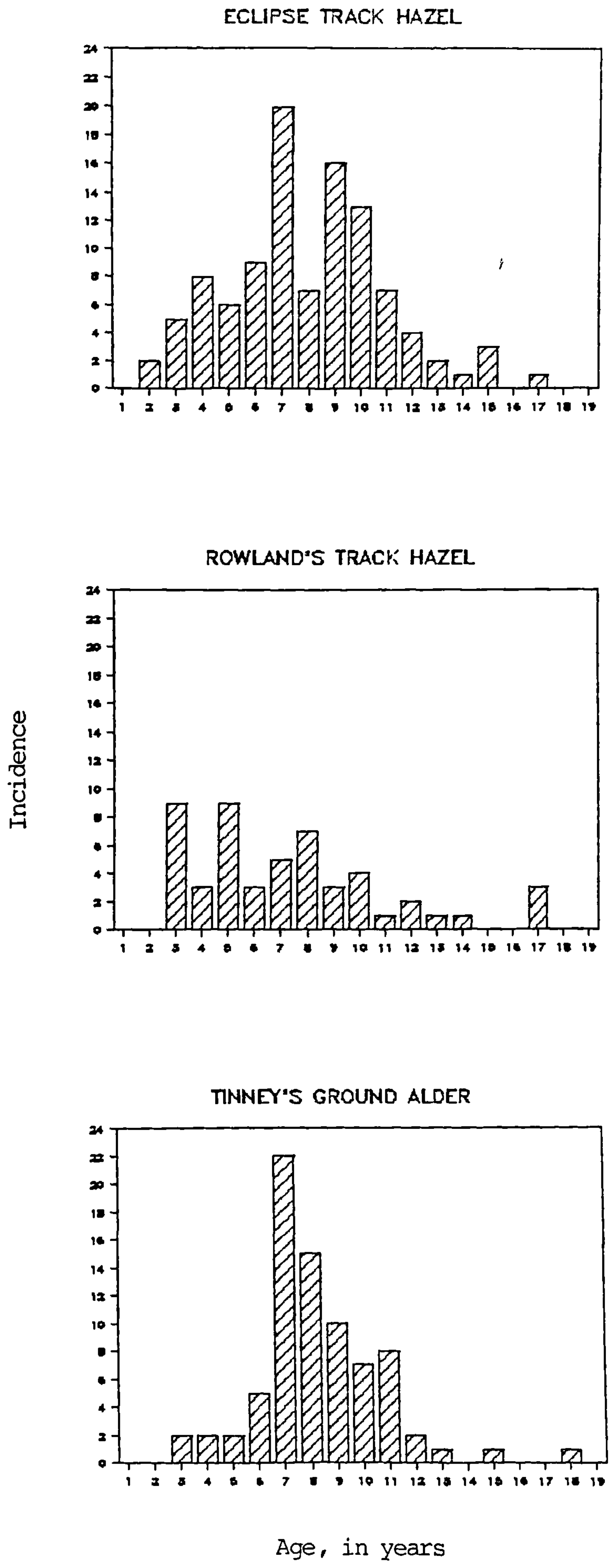


Fig.82 Modern Hazel Coppice; age structure of "drawn" data

Modern Alder; t-values for coppiced and unmanaged alder



ECLIPSE TRACK HAZEL

ROWLAND'S TRACK HAZEL

TINNEY'S GROUND ALDER

Fig.83 Age structure of three Somerset Levels trackways

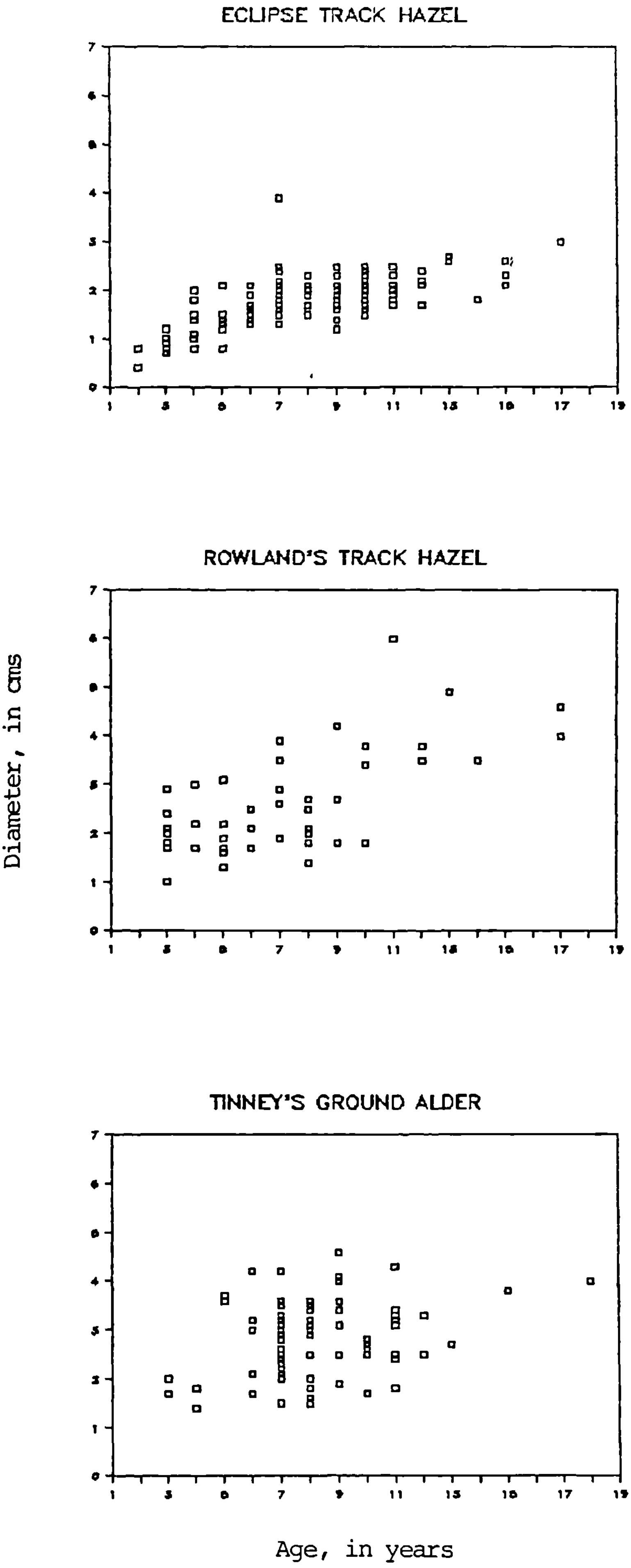


Fig.84 Age/size relationships of three Somerset Levels trackways

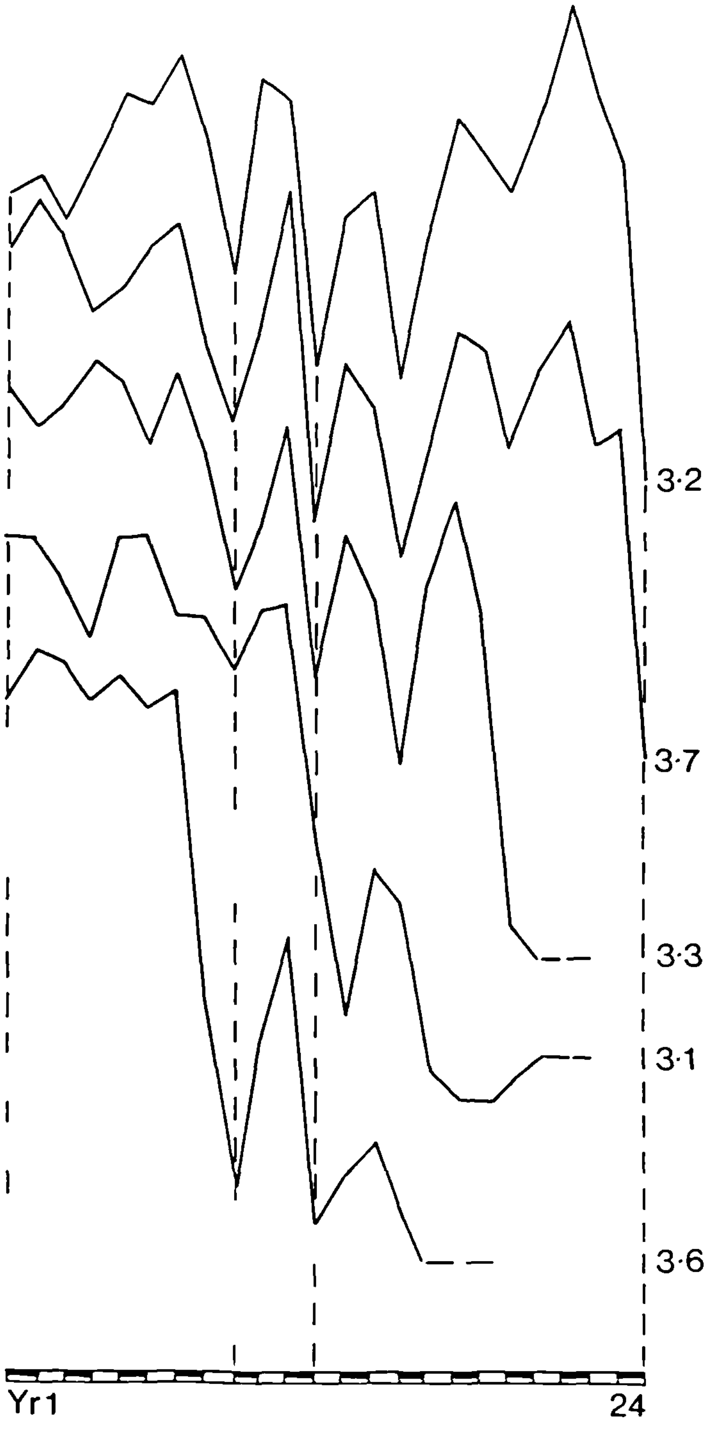
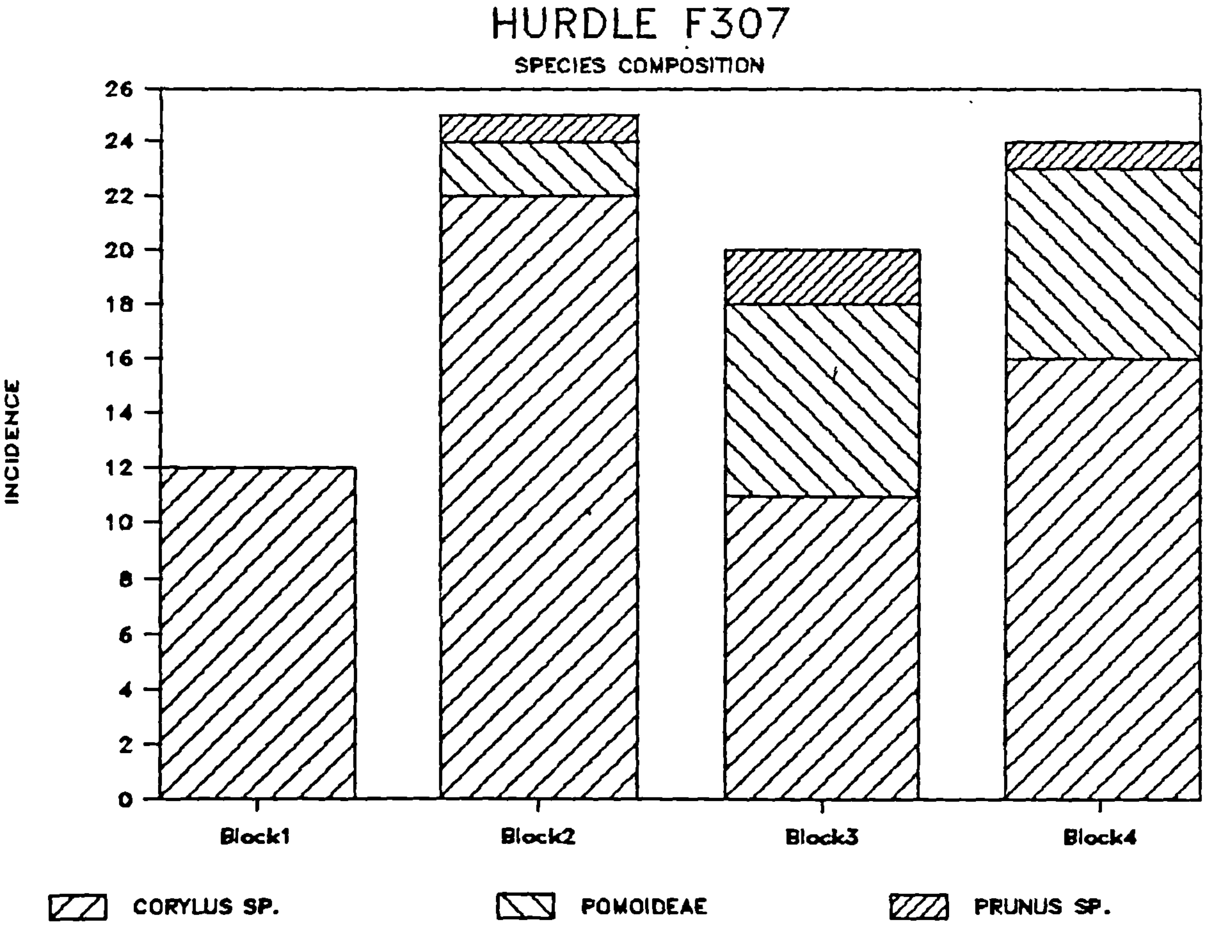


Fig.85 Modern Alder Coppice; suppressed growth



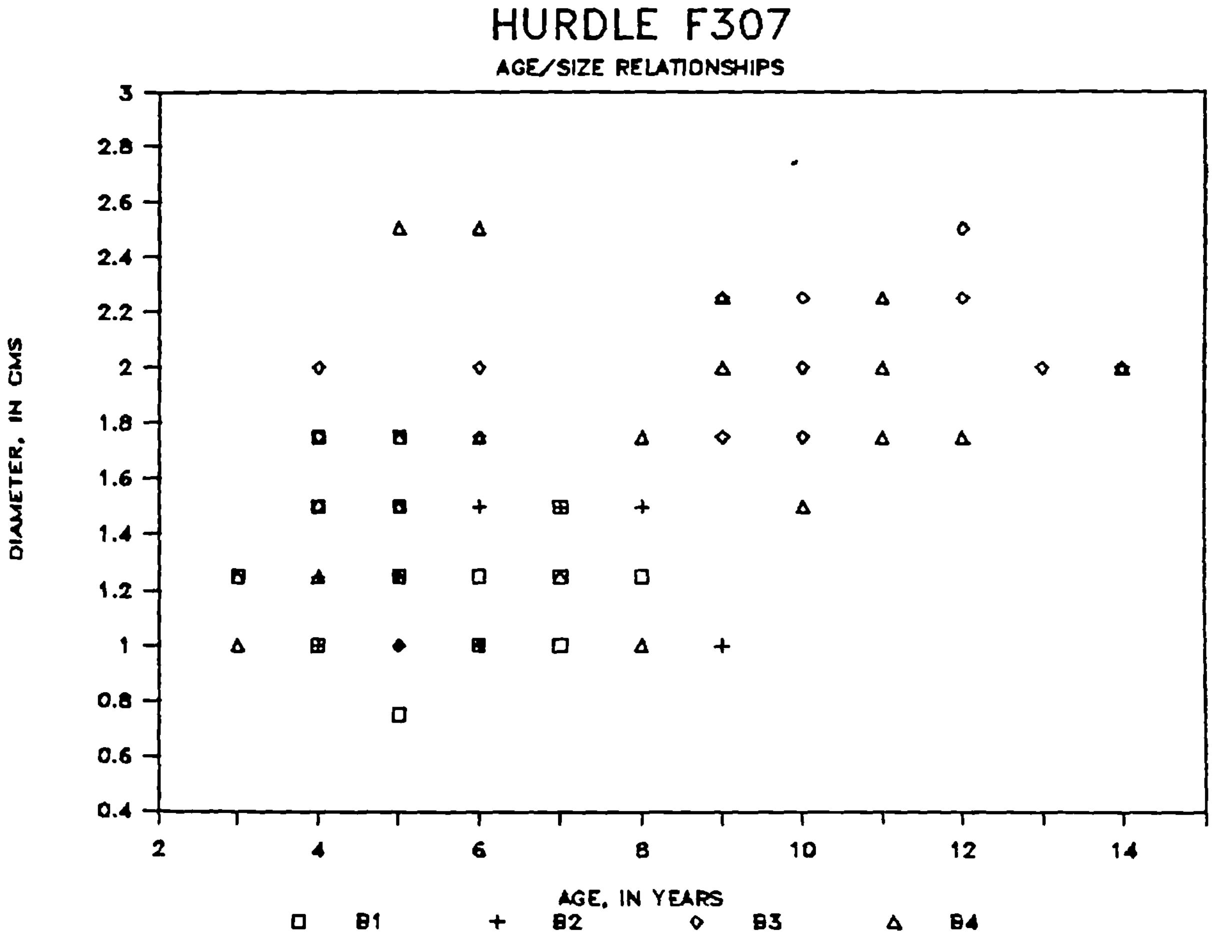
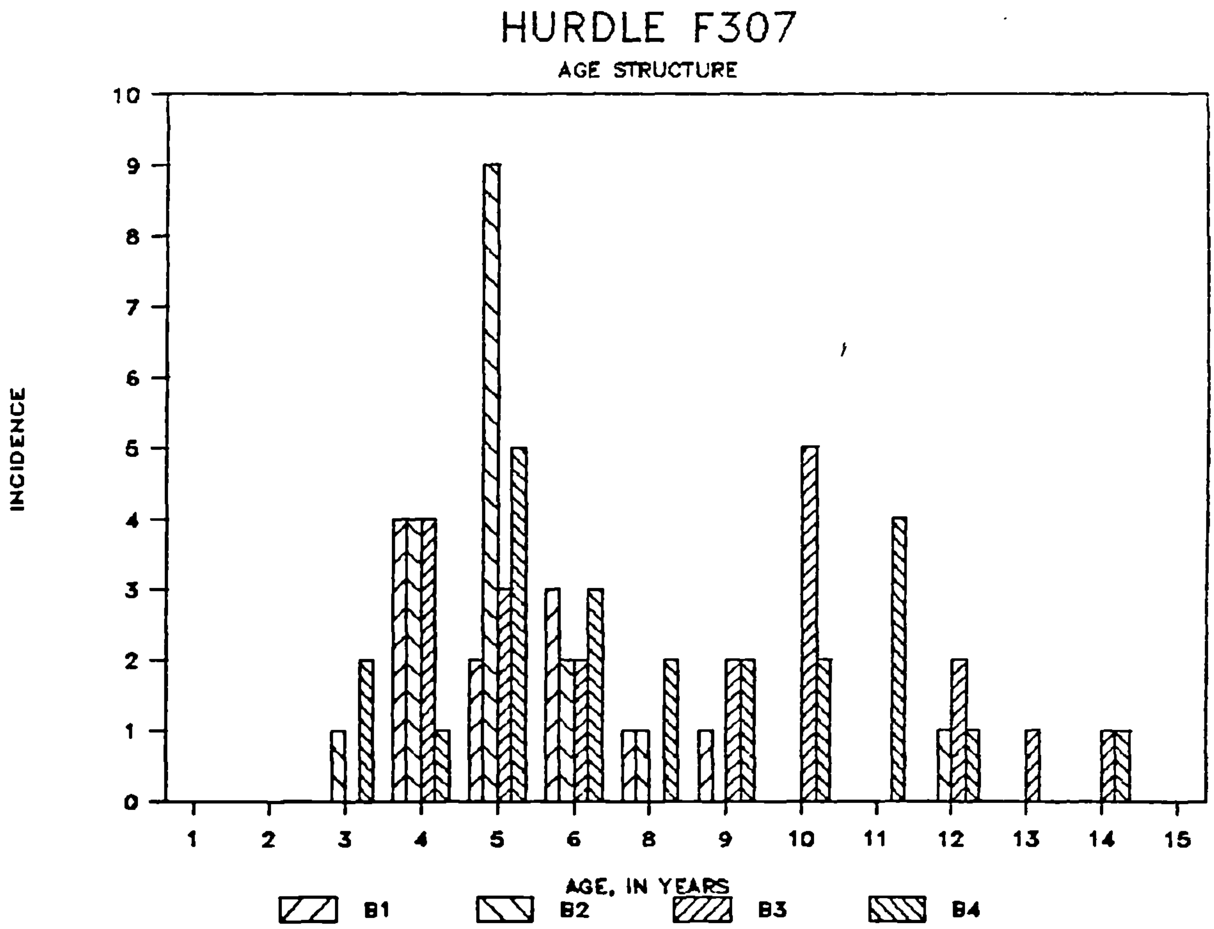


Fig.86 Hurdle F307; species composition and age/size relationships



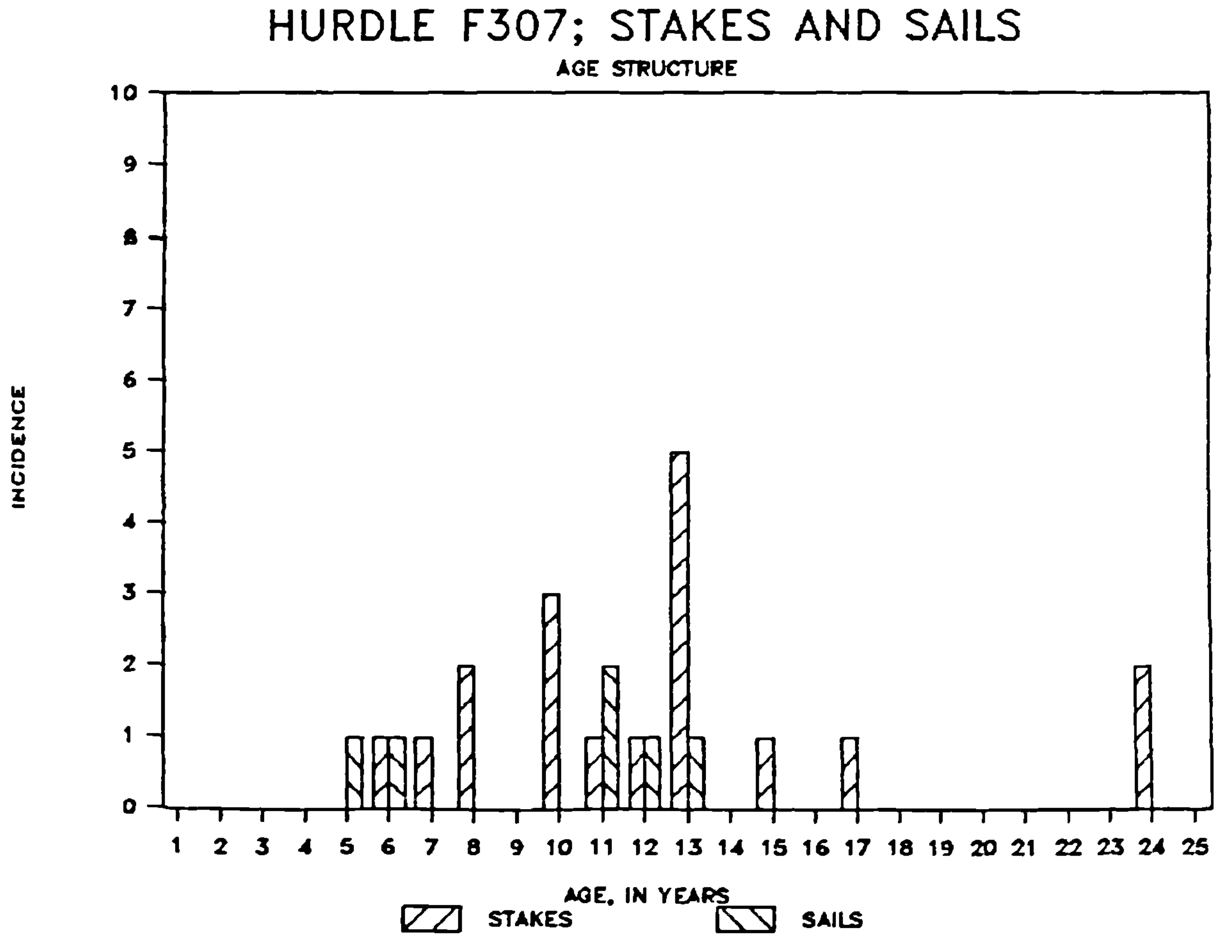
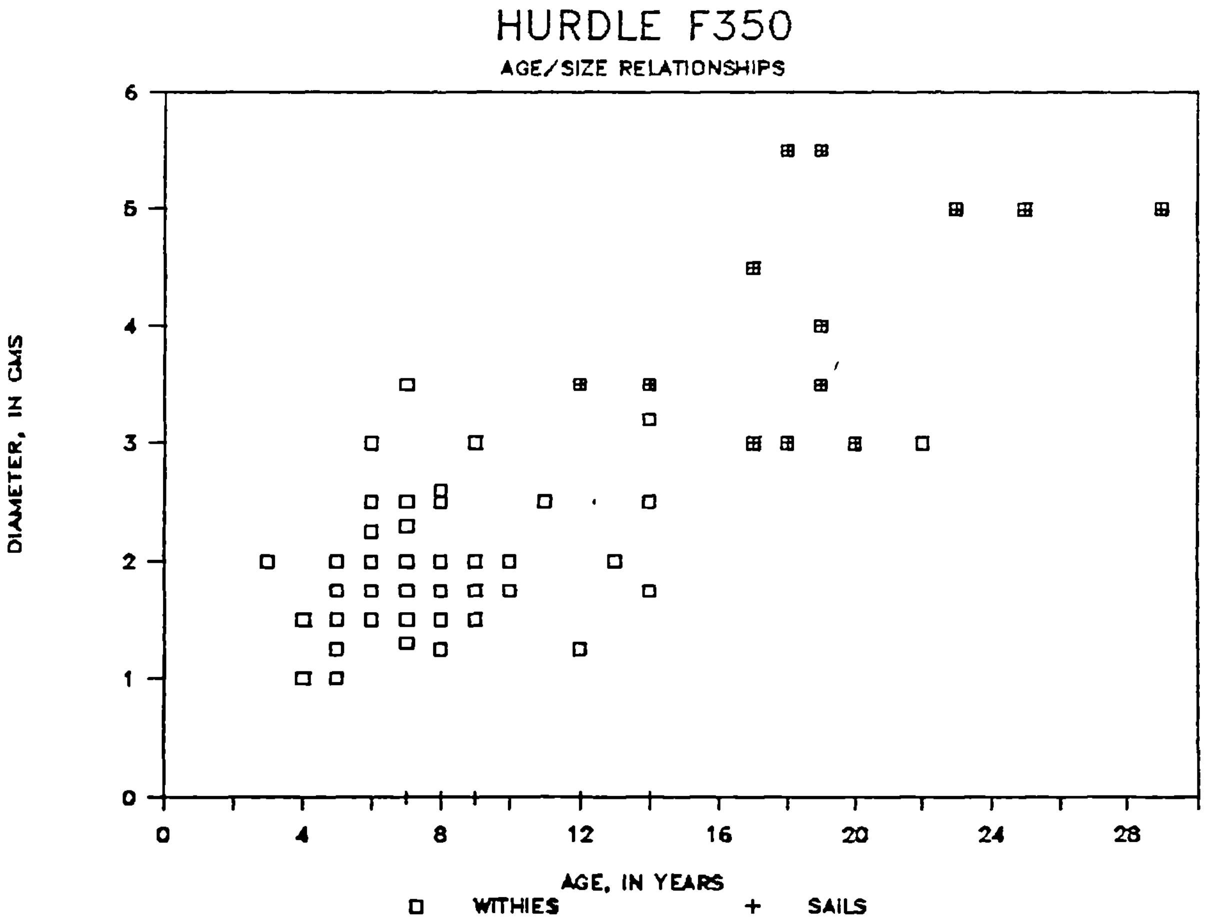


Fig.87 Hurdle F307; age structure of withies, stakes and sails



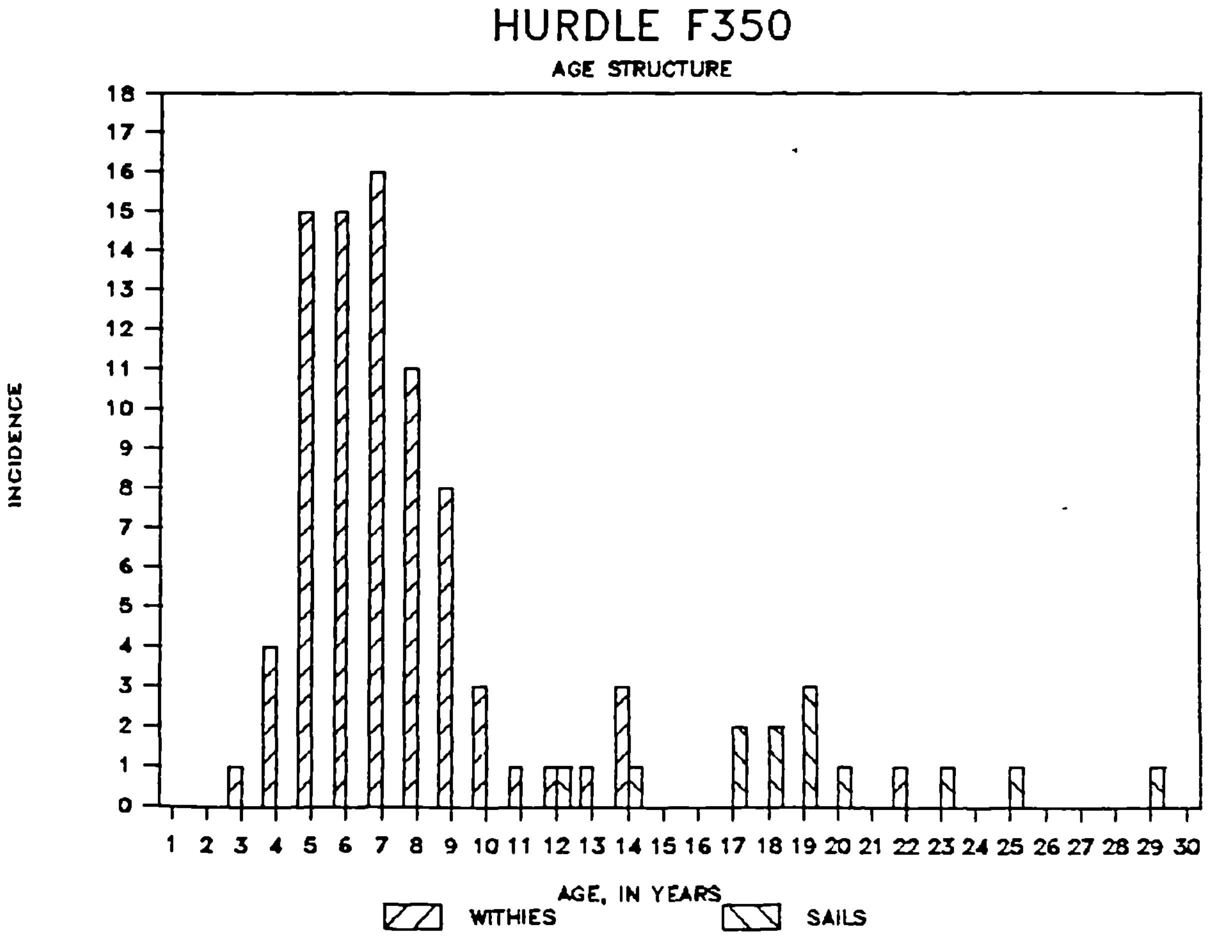


Fig.88 Hurdle F350; age/size relationship and age structure

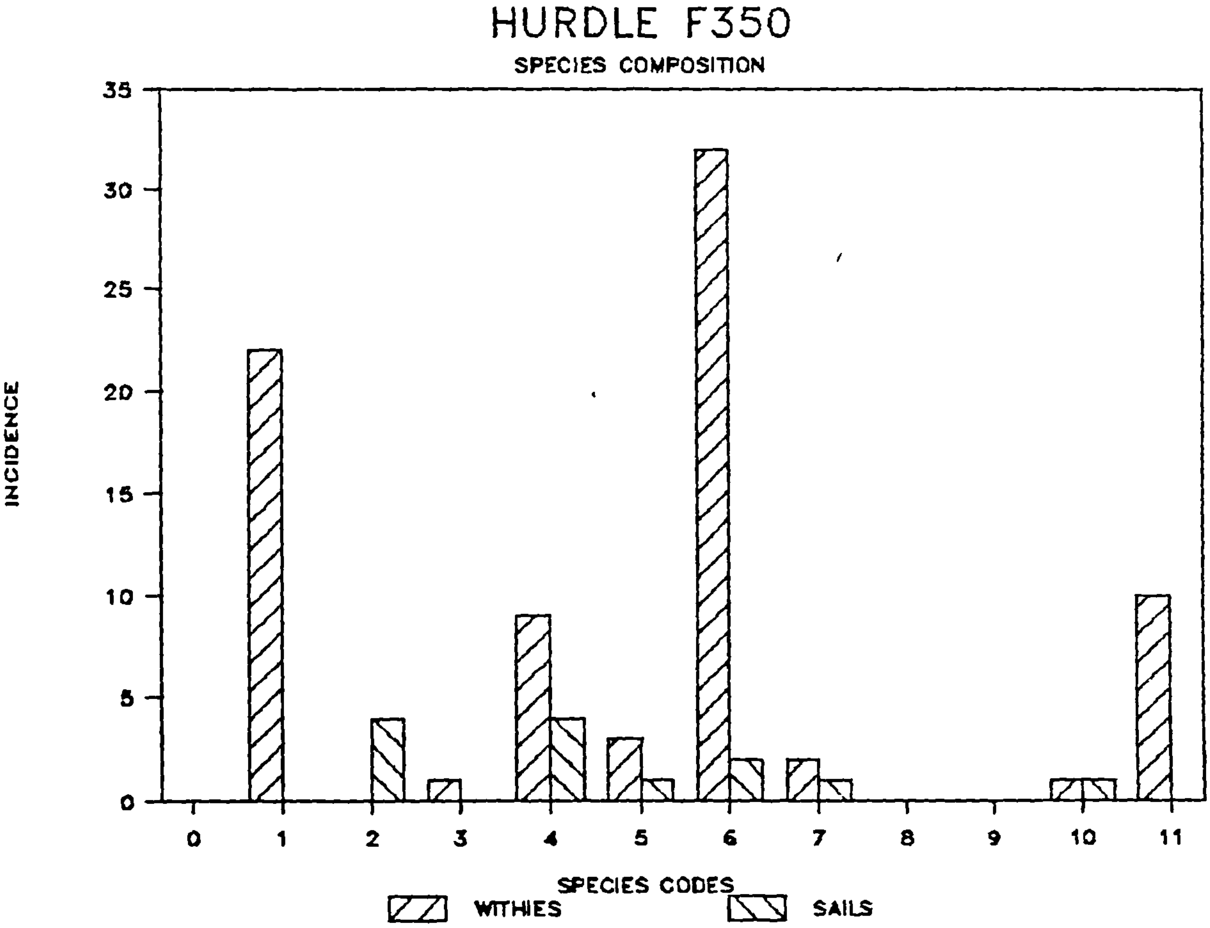


Fig.89 Hurdle F350; species composition

APPENDIX 2

PLATES

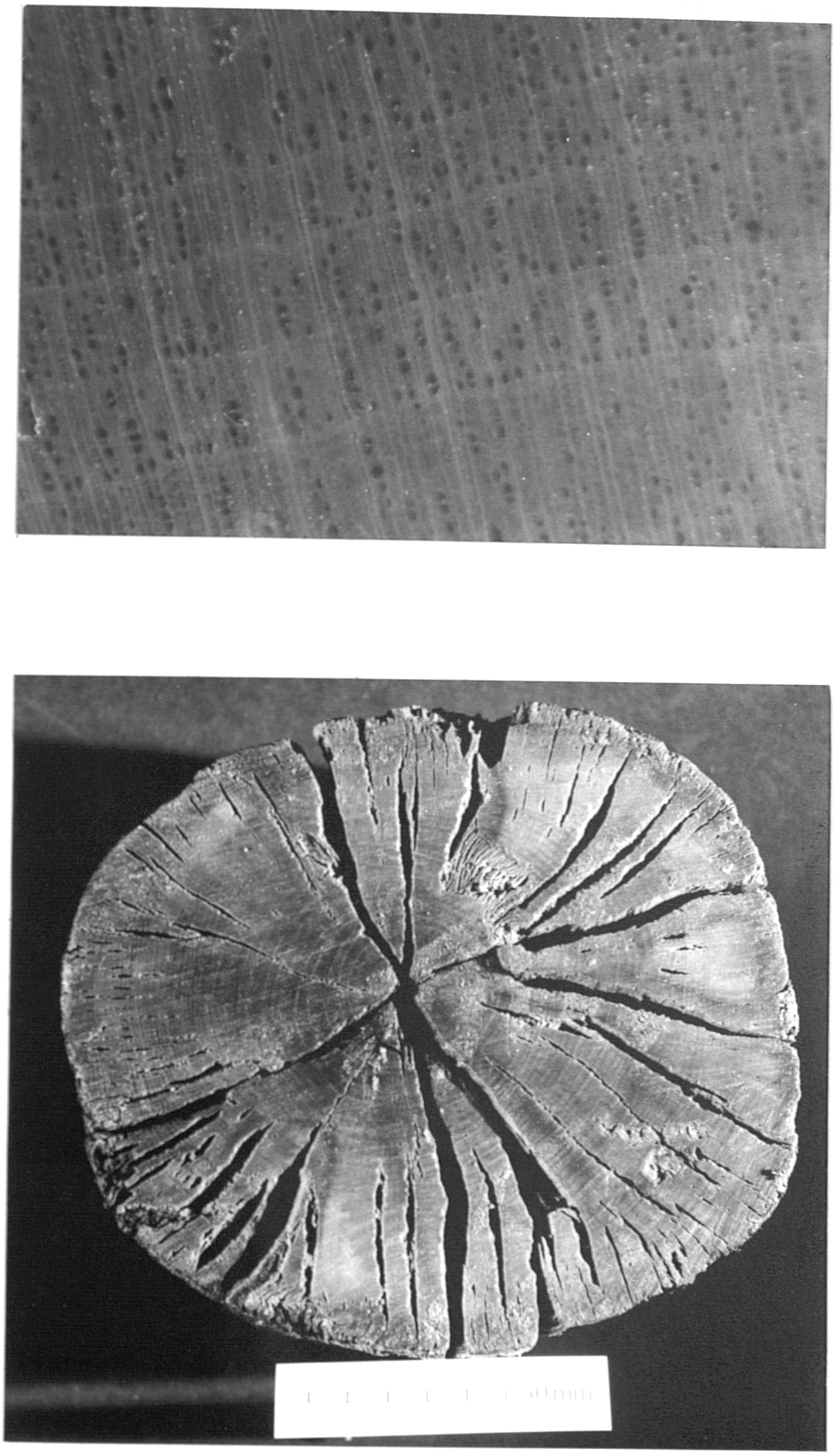
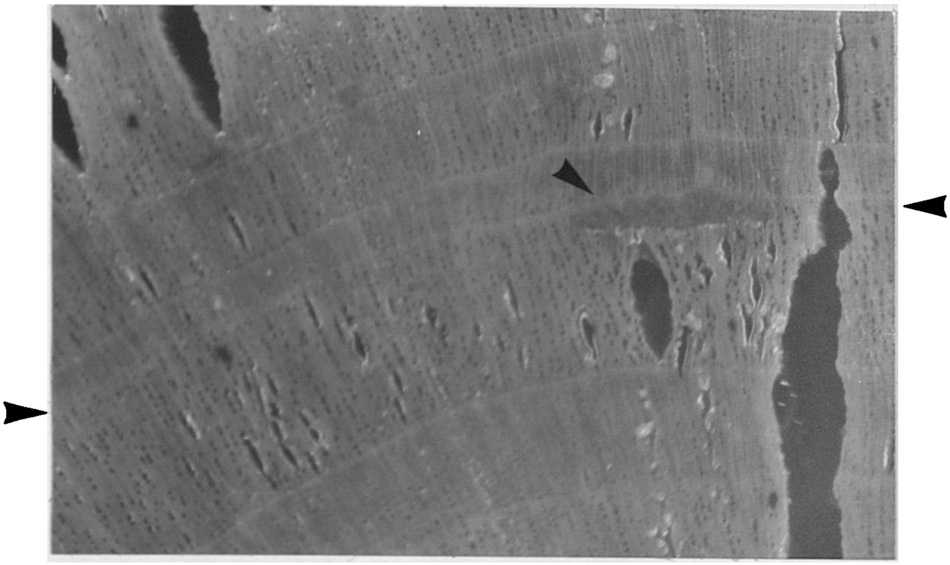


Plate 1 Alder; a) transverse section (x40)

b) radial splitting after thawing



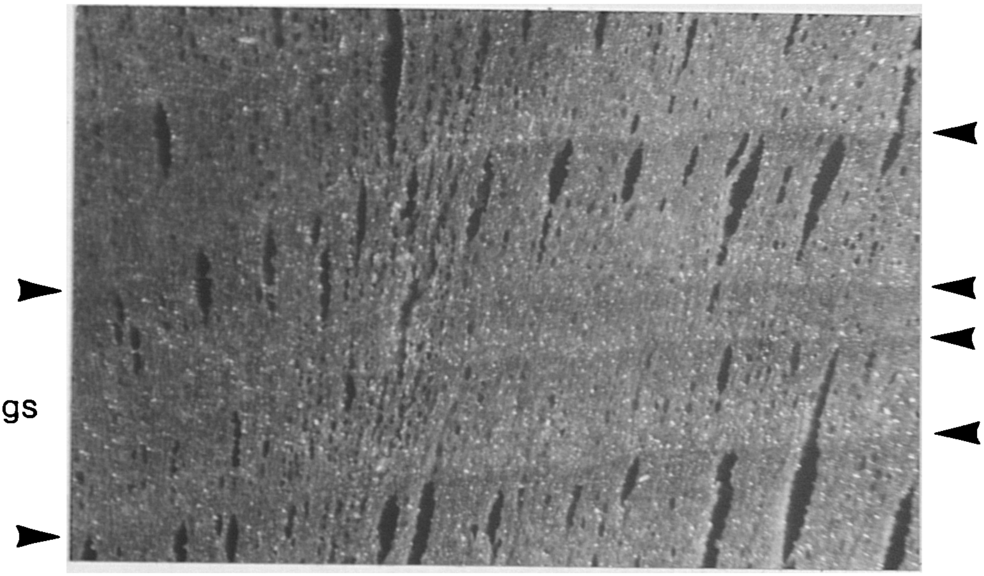


Plate 2 Alder; a) "Markflecke" (x16)

b) indistinct ring boundaries (x16)

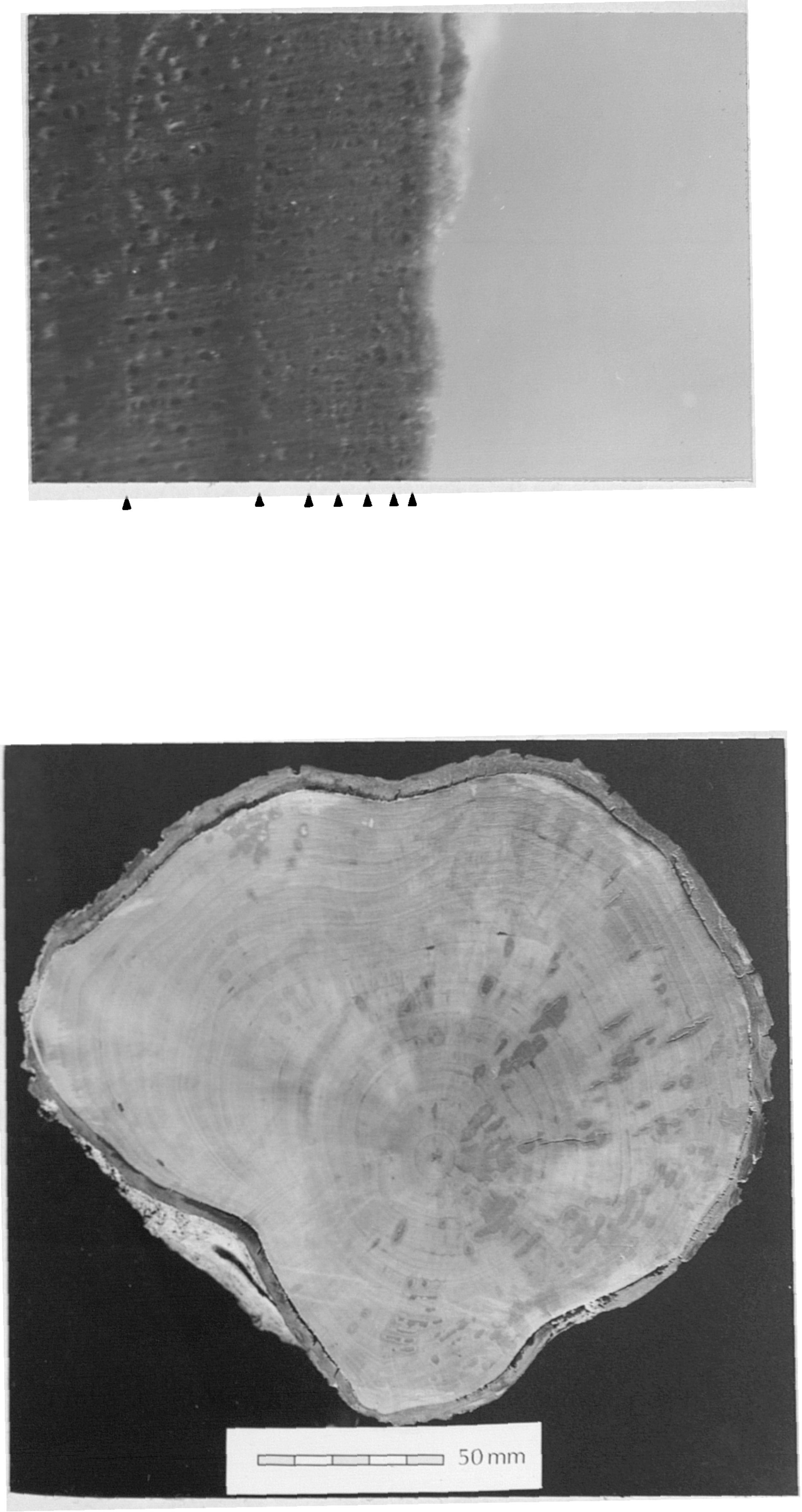


Plate 3 Alder; a) compressed outer rings (x40)

b) assymetric growth

APPENDIX 3

TABLES

TABLE 1 Moynagh Lough; Dendrochronological Samples

Sample No.	Context	Species	Age	Extra Rings	Diameter	Felling Season	Conv Code	Q.U.B. S. No.	Comments
1	CWAY	5	47		7				
2	CWAY	5	50		7.5				
3	CWAY	2	19		9				
4	CWAY	2	19		9				
5	CWAY	3	32		8.5	S			
6	CWAY	2	49		8				
7	CWAY	5	32		9	S			
8	unsampled								
9	CWAY	3	30		6	W			
10	CWAY	2	27		9.5				
11	CWAY	5	36		10				
12	CWAY	4	14		2.5				Unprocessed
13	CWAY	3	12		5				Unprocessed
14	CWAY	2	0		8				Unreliable sequence
15	CWAY	4	35		7.5				
16	CWAY	3	24		8				
17	CWAYF	6	35		4				
18	CWAYF	6	17		6				
19	CWAYF	6	25		4				
20	CWAY	5	48		7.5				
21	unsampled								
22	CWAY	2	14		8				Unprocessed
23	CWAYF	6	29	plus	8				Unreliable sequence
24	CWAY	3	25		8				
25	CWAY	1	12		6.5				Unprocessed
26	CWAY	3	28	plus	5.5				Unmeasurable
27	CWAY	1	17		5	W			
28	CWAYF	6	0		9.5				Unmeasurable
29	CWAY	6	0		7	S			Unmeasurable
30	CWAY	3	20		7	S			
31	CWAY	2	24		8	S			
32	CWAY	5	17		6	S			
33	CWAY	6	26		5				
34	CWAY	6	19		5				
35	CWAY	6	0		4				Unmeasurable
36	CWAY	6	30		4				
37	CWAY	2	32		10	S			
38	CWAY	2	31		11	W			
39	CWAYF	3	45		4	S			
40	CWAY	6	0		10				Unmeasurable
41	CWAY	6	44	plus	13				No match between radii
42	CWAY	6	23		6				
43	CWAY	6	25		5.5				
44	CWAY	8	32		7.5				
45	CWAY	1	28	plus	8				Outer rings compressed or distorted
46	CWAY	6	23		5.5	S			
47	PAL2	1	23		9.5	S			
48	PAL2	1	35		14	S			
49	PAL2	1	56	plus	8				No match between radii
50	PAL2	1	33		11	S			
51	PAL2	1	39	plus	11	S			Centre missing
52	PAL2	1	30		11	S			
53	PAL2	1	24		9	W			
54	PAL2	1	22		10	S			

55	PAL2	1	52	10			
56	PAL2	1	26	10	S		
57	PAL2	1	29	10	S		
58	PAL2	2	8	7			Unprocessed
59	PAL2	1	38	8.5	S		
60	PAL2	1	36 plus	11			Centre missing
61	PAL2	1	28	9	S		
62	PAL2	1	23	10	S		
63	PAL2	1	25	11			
64	PAL2	1	26	10	S		
65	PAL2	1	35 plus	10			Outer rings compressed or distorted
66	PAL2	1	70 plus	12			One radius only
67	PAL2	1	22	8	W		
68	PAL2	1	27	10	S		
69	PAL2	6	6	4			Unprocessed
70	PAL2	1	22	9	S		
71	PAL2	3	30	10	S		
72	PAL2	1	36	10			
73	PAL2	1	29	11	S		
74	PAL2	3	26	10	S		
75	PAL2	6	21	9			
76	PAL2	1	23	8	S		
77	PAL2	6	21	9.5			
78	PAL2	1	36	12	S		
79	PAL2	1	46 plus	8.5	S		Centre unmeasurable
80	PAL2	1	22	10	S		
81	PAL2	1	22	12	S		
82	CWAYF	1	37	7	S		
83	CWAYF	6	0	4			Unreliable sequence
84	CWAYF	6	40	7.5			
85	CWAYF	5	19	7		B	
86	CWAY	1	13	5			Unprocessed
87	CWAY	1	17	5.5	W		
88	CWAY	1	17	6.5	W		
89 unsampled							
90	CWAY	3	23	12	W		
91	CWAY	3	32	8	W		
92	CWAY	3	32	8	W		
93	CWAY	5	23	9			
94	CWAY	3	35	6.5	S		
95	CWAY	4	23	4	S		
96	CWAY	1	14	5.5			Unprocessed
97	CWAY	1	23	6	W		
98	CWAY	3	21	7	S		
99	CWAY	3	61	7	S		
100	CWAY	3	31	9	S		
101	CWAY	3	41	10			
102	CWAY	3	33	8	W		
103	CWAY	3	33	8			
104	CWAY	5	31	8.5			
105	CWAY	5	52	8			
106	CWAY	3	48	7	S		
107	CWAY	3	55	7.5	S		
108 unsampled							
109 unsampled							
110	ST3	1	34	10			
111	ST3	1	39	9	S		
112	ST3	1	15	9	S	C	
113	PAL2F	7	0	9			Unmeasured
114	ST1	4	21	7.5			

115	ST1	4	13	4.5			Unprocessed
116	ST1	4	21	5	S		
117	ST1	4	9	3.5			Unprocessed
118	ST1	4	0	4.5	S		Unmeasurable
119	ST1	4	28	5.5			
120	ST1	4	17	3			
121	ST1	4	13	4.5			Unprocessed
122	PAL3	3	25	8	S		
123	PAL3	3	29	7	S		
124	PAL3	1	18	9	S	C	
125	PAL3	4	31	7			
126	PAL3	1	18	6			
127	PAL3	1	13	6			Unprocessed
128	PAL3	1	14	8	W		Unprocessed
129	PAL3	1	21	6			
130	PAL3	1	26	6			
131	PAL3	1	18	8			
132	PAL3	1	19	7.5			
133	PAL3	1	20	8.5			
134	PAL3	1	22	9.5	S		
135	PAL3	4	30	7			
136	PAL3	1	11	6			Unprocessed
137	PAL3	10	0	6.5			Unmeasurable
138	PAL3	1	15	11.5			
139	PAL3	1	20 plus	10	S		Centre missing
140	PAL3	1	16	7			
141	PAL3	1	22	11	S		
142	PAL3	1	19	5.5			
143	PAL3	1	28	9.5	S	B	
144	PAL3	1	21	6.5			
145	PAL3	1	22	9.5	S		
146	PAL3	3	11	8.5			Unprocessed
147	PAL3	4	30	5			
148	PAL3	6	13	6			Unprocessed
149	PAL3	4	38 plus	8			No match between radii
150	PAL3	4	13	5			Unprocessed
151	ST3	1	24	13	S		
152	PAL2A	1	20	7			
153	PAL2A	3	43	7			
154	PAL2A	1	21	7.5			
155	PAL2A	1	20	6.5			
156	PAL2F	1	11	6	S		Unprocessed
157	PAL2A	3	43	6			
158	PAL2A	7	0	7			Unmeasurable
159	PAL2A	1	29	8.5	S		
160	PAL2F	1	11	6.5			Unprocessed
161	PAL2F	1	26	6	S		
162	PAL2	1	19	7.5			
163	PAL2F	1	11	7			Unprocessed
164	ST3	3	16	6.5			
165	PAL2	4	23	7.5			
166	PAL2	4	24	7.5			
167	PAL2	1	22	7.5			
168	PAL2	1	21	7			
169	PAL2	1	18	9.5			
170	PAL2	4	36 plus	7.5			No match between radii
171	PAL2	1	13	7.5			Unprocessed
172	PAL2	1	20	9			
173	PAL2	1	19	5	S		
174	PAL2	4	57 plus	7			No match between radii

175	PAL2	1	0	6.5				Missing
176	PAL2	1	16	7				
177	PAL2	1	46 plus	9				Outer rings compressed or distorted
178	PAL2	1	11	5.5	S			Unprocessed
179	PAL2	1	19	5.5				
180	PAL2	3	23	8	S			
181	PAL2	1	16	7				
182	PAL2	2	30	7.5				
183	PAL2	1	23	7				
184	PAL2	1	19	6.5				
185	PAL2	1	19	5				
186	PAL2	1	23	5.5				
187	ST3	4	17	7				
188	PAL1	1	75 plus	13.5		D1		
189	PAL1	1	40 plus	11.5		D1		
190	PAL1	1	32 plus	5		D/E		
191	PAL1	1	40 plus	24		D	4394 H/S	
192	PAL1	1	29 plus	18		D/E	4396	
193	ST4	1	28 plus	22		C	4391	
194	ST4	1	65	20			4390	
195	ST4	1	22 plus	14		D/E	4392	
196	unassoc	1	139 plus	0		D1	4388	
197	ENT	1	385 plus	44		D1	5942	
242	unassoc	1	109 plus	40		D1		

CONTEXT; PAL1 = Palisade 1; PAL2 = Palisade 2; PAL2A = Palisade 2A; PAL2F = Palisade2 "floating";
CWAY = Causeway; CWAYF = Causeway "floating"; ST1-4 = Stakelines 1-4; ENT = Entrance

SPECIES; 1 = OAK; 2 = ALDER; 3 = ASH; 4 = HAZEL; 5 = BIRCH; 6 = WILLOW; 7 = POMOIDEAE; 8 = POPLAR; 9 = ELM;
10 = HOLLY

EXTRA RINGS; See Text

FELLING SEASON; S = Summer; W = Winter

CONV CODE; See Crone & Barber, 1981, for explanation

Q.U.B. S. Nos = Queen s University, Belfast

TABLE 2 Oakbank; Dendrochronological Samples

Sample No	Context	Species	Age	Extra Rings	Diameter	Outer Rings	Comments
3	F8	2	46		15.5		
15	F5	2	23		15.5	2	
30	F8	2	23		11	2	
33	F8	2	24		13		
44	F1	2	29		15		
62	F5	2	24		12		
64	F5	1	18		6.5		
65	F8	2	52		14	3	
74	F19	2	17		14		
84	F16	1	101		24		H/S
88	F1	2	49		17		
93	F16	1	112		40		H/S
99	F19	1	13		9		Unprocessed
100	F1	2	16		9		
103	F10	1	87		27		H/S; 595+55bc
104	F14	2	25		17	2	
107	F9	1	22		18		H/S
108	F10	2	25		18		
109	F3	2	22		11.5		
112	F1	2	24		12	2	
116	F3	6	41		23		
121	G4	2	21	plus	19		No match between radii
124	F3	2	23		11		
125	F9	2	19		7	3	
129	F5	2	24		11.5		
130	F5	1	11		4		
131	F19	1	9		4		
132	F5	2	31		9		
133	F1	2	19		13.5	2	
134	F5	1	11		6		
141	F16	1	80		22		H/S
164	G4	4	0		4		Unmeasurable
166	F5	2	16		11		
168	F18	4	15	plus	4		
169	G4	3	0		4		Unmeasurable
171	F5	2	22		14		One radius only
172	F5	2	21		11.5		
179	F1	2	22		16		
181	G4	2	24		8.5		
200	G4	2	37		10		No match between radii
207	F17	1	20		11		H/S
208	F17	7	0		11		
214	F22	2	20		8.5		
216	F22	2	11		5.5		Unprocessed
301	F17	2	22		9	2	
302	F17	7	0		9		
304	F17	1	18		5		
306	F17	4	16		6		Unprocessed
307	F17	1	20		8		
308	F17	2	28		14		
309	F17	2	27		15.5		
310	F17	2	21		11		
313	F17	2	31		15	2	

315	F17	5	0	6		
316	F17	7	0	4		
318	F17	4	24	6		
320	F17	4	0	8		Unmeasurable
322	F17	4	37	6		
324	F17	1	29	5.5		
325	F17	4	15	4.5		Unprocessed
326	F17	2	37	8		
327	F17	1	19	13		
328	F17	1	74 plus	8		H/S
329	F17	1	53 plus	9		H/S
330	F17	9	0	10		
332	F17	1	81	9		H/S
333	F17	2	14	5		Unprocessed
334	F17	2	11	4.5		Unprocessed
335	F17	1	22	0		
336	F17	1	78	9.5		H/S
338	F17	1	67	7		H/S
340	F17	1	52	8		H/S
341	F7	2	22	7.5		
342	G2	2	21	11		
343	G2	2	20	10.5		
345	G2	2	24	12.5		
346	F7	2	24	18		
349	F6	2	45	19	3	
350	F17	2	15	7		Unprocessed
351	F17	2	12	10		Unprocessed
353	F17	2	20	8		
354	F17	7	0	12		
356	F17	1	44	9		H/S
357	F17	2	17	10	6	
358	F17	2	21	11	3	
361	F7	1	15	9		
365	G4	4	16	3		
369	F16	1	66	23		H/S
370	F16	1	47	16		H/S
372	F16	1	28	13.5		H S
376	F4	2	51	20	5	
378	F4	2	11	10.5		Unprocessed
379	F4	2	45	20	3	
380	F2	1	98	30		H/S
381	G4	2	28	6.5	2	
383	G4	1	61	6		H/S
384	F4	2	27	12	3	
385	F4	2	24	14		
386	F6	2	22	17		
387	F6	2	22	10.5	3	
391	F7	2	29	12		
392	F7	1	25	14		H/S
399	F7	1	25	8		
400	F7	2	25	10	5	
401	F7	2	17	8		
402	F7	1	40	7		H/S
403	F17	2	21	9.5	2	
406	F17	1	16	5.5		Unprocessed
407	F17	1	14	7		Unprocessed
408	F17	2	21	12	3	
409	F17	1	30	4.5		
411	F17	1	20	11.5		
412	F17	2	28	10		No match between radii

413	F17	7	0	6		
414	F17	1	39	7.5		
415	F17	1	16	6.5		Unprocessed
417	F17	1	16	8		Unprocessed
418	F7	2	16	11		
419	F7	2	19	14	2	
420	F7	2	24	16	2	
421	F7	2	28	16		
422	F6	2	43 plus	18		No match between radii
423	F17	1	28	8		H/S
424	G2	2	20	11		
426	G4	2	0	5.5		Unmeasurable
427	G4	1	11	5		Unprocessed
428	G4	4	23	6.5		
431	F7	2	15	7		Unprocessed
432	G4	1	16	6		
433	G4	4	17	3		
434	G4	4	15	4		
446	G1	2	71 plus	19		
447	G1	2	20	7.5	2	
452	G4	1	67	14		H/S
453	F11	9	0	24		
454	F11	9	0	19		
455	F11	6	39	17.5		
459	G4	2	19	7.5		
460	G4	2	18	8.5	4	
461	G4	4	27	7		
462	G4	2	30	15		
465	G4	5	0	2		
466	G3	2	20	9		
467	F11	1	18	8		
471	F11	2	26	11		
473	F16	1	138	32		H/S
477	G4	5	57 plus	8.5		
480	G4	1	14	4		Unprocessed
481	F11	2	32	14	2	
482	G4	2	17	9		
484	G4	4	21	9		
487	G3	2	23	12.5		
488	F11	4	29	8		
489	F2	2	7	5		Unprocessed
490	G1	2	26	12	3	
491	G1	2	13	7.5		Unprocessed
496	G4	2	0	9		Unmeasurable
497	G3	1	86	24		
499	F6	2	27	14	2	
504	F6	2	50	23		
505	F6	2	60	12		
506	F6	2	29	20		
511	G4	2	16	7		
512	F6	1	62	6		
513	G4	4	27	4		
514	G4	7	0	4		
515	G4	4	15	4		
516	G4	2	11	5		Unprocessed
517	G4	1	19	6		
518	G4	2	8	4		Unprocessed
519	F24	2	41	8		No match between radii
520	F24	2	19	7	5	
521	F24	2	11	4.5		Unprocessed

522	F24	2	17		6	2	
523	F24	2	21	plus	5.5		
525	F24	2	20		9	2	
527	F24	2	34		7	3	
529	F24	4	16		3.5		Unprocessed
532	f24	7	0		6		
533	F24	2	22		7		
534	F24	2	32		12		
536	F24	2	19		7		
538	F24	1	29	plus	13.5		Parts unmeasurable
541	F24	7	0		7		
542	F24	1	54		6.5		
543	G5	1	19		6		
547	G5	2	14		5.5		Unprocessed
548	G5	2	19		6.5		
550	G5	2	16		7	3	
553	G5	2	13		6		Unprocessed
555	G5	2	23		5.5	5	
556	G5	2	13		6		Unprocessed
557	G5	2	12		5.5		Unprocessed
558	G5	2	12		4.5		Unprocessed
559	G5	2	0		5		Unprocessed
561	G5	4	31	plus	7		
564	G5	4	31		5		
571	G5	4	19	plus	4		
582	G5	4	26		5		
584	G5	2	18		6		
585	F24	2	22		8	2	
589	F24	2	24		11		
600	G1	2	19		10		
603	G1	2	53		11		
604	G1	2	24		12		
605	G1	2	53	plus	12		No match between radii
606	G1	2	55		12.5	2	
608	G1	4	62		10		
613	G1	2	26		13		
616	G1	2	60		12.5	9	
618	G1	2	57		13		
620	G4	2	38		8		
621	G4	1	21		8.5		H/S
628	G4	7	0		4		
629	G4	4	33		7.5		
630	G4	7	0		5		
637	G3	2	22		8		
x1	G6	2	33		16		
x2	G6	2	35		14		
x3	G6	2	33		15.5		
x4	G6	2	60		24		
x5	G6	2	41		14		
x6	G6	2	33		16		
x7	G6	6	51		20		
x8	G6	6	53		25		
x9	G6	2	47		18		
x10	G6	2	36		12		
x11	G6	2	45		15		
x12	G6	2	26		18		
x12a	G6	2	44		17		
x13	G6	2	37		19		
x14	G6	2	20		16		
x15	G6	2	50		27		

x16	66	2	50	15	
x17	66	2	25	14	
x18	66	2	19	15	
x19	66	2	19	14.5	
x20	66	2	21	17	
x21	66	2	30	14	
x22	66	2	25	16.5	
x23	66	2	27	15	
x24	66	2	32	14	
x25	66	2	35	17	
x26	66	2	21	14	
x27	66	2	21	14	
x28	66	2	27	13	
x29	66	2	32	15	
x30	66	2	23	12	
x31	66	2	29	18	
x32	66	2	28	13.5	
x33	66	2	49	19	
x34	66	2	31	13	
x35	66	2	26	12.5	
x36	66	2	25	12	
x37	66	2	29	18	
x38	66	2	22	22	
x39	66	2	25	12	
x40	66	1	113	113	H/S; 460+80bc

CONTEXT; See text for explanation

SPECIES; 1 = OAK; 2 = ALDER; 3 = ASH; 4 = HAZEL; 5 = BIRCH; 6 = WILLOW;
7 = POMOIDEAE; 8 = POPLAR; 9 = ELM; 10 = HOLLY

OUTER RINGS; See text for explanation

TABLE 3 Hypothetical SORT.STRING matrix

	Sequence No.s	
STRING A	1,2,3,4,5,6,7,8,9,10	= TARGET 1
STRING B	1,2,4,5,7,8,10,11,12	)
STRING C	2,4,6,7,9,10,13	) EXTENSION
STRING D	2,3,4,6,8,9,12,14,15	)
STRING E	4,5,6,13,14,16	)

	S.No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	1	0															
	2	X	0														
	3	X	X	0													
	4	X	X	X	0												
	5	X	X	X	X	0											
	6	X	X	X	X	X	0										
	7	X	X	X	X	X	X	0									
	8	X	X	X	X	X	X	X	0								
	9	X	X	X	X	X	X	X	X	0							
	10	X	X	X	X	X	X	X	X	X	0						
from STRING B	11	X	X	0	X	X	0	X	X	0	X	0					
from STRING B	12	X	X	0	X	X	0	X	X	0	X	X	0				
from STRING C	13	0	X	0	X	0	X	X	0	X	X	0	0	0			
from STRING D	14	0	X	X	X	0	X	0	X	X	0	0	X	0	0		
from STRING D	15	0	X	X	X	0	X	0	X	X	0	0	X	0	X	0	
from STRING E	16	0	0	0	X	X	X	0	0	0	0	0	0	X	X	0	0

X = maximum z-value

TABLE 4 Modern Alder; Dendrochronological Samples

Sample No.	Age	Diam.	T-value for radii matches
1.1	24	12	3.3
1.2	18	15	1.7
1.3	25	11.6	NO MATCH
1.4	25	21.6	0.6
2	18	16.2	1.1
3	28	17	3.4
4.1	26	20.6	2.7
4.2	29	17.4	1.4
4.3	31	24.1	7.9
4.4	30	15.8	3.8
5.1	25	20	8.1
5.2	23	9.4	7.9
5.3	ROTTEN CORE		
5.4	25	10	7
6	32	18.6	1.4
7	39	19.5	4.1
8	33	12.5	1.1
9.1	26	11	1.8
9.2	0	6.2	UNMEASURABLE
10	32	12.8	8.4
11	43	31	4.6
12	52	22.6	5.9
13	0	33	UNMEASURABLE
14	20	16	2.9
15	27	19	8.1
16.1	27	13.5	0.2
16.2	27	7	3
17	25	14	7
18.1	26	17.5	6.8
18.2	25	17.5	4.6
19.1	14	7	UNPROCESSED
19.2	38	14	3.6
20.1	17	15	3
20.2	25	15	8
20.3	26	9	6.1
21.1	35	15	5.3
21.2	36	13.5	5
21.3	33	16	3.1
22	72	27	3
23.1	13	8	UNPROCESSED
23.2	11	10	UNPROCESSED
23.3	14	11.5	UNPROCESSED
23.4	14	9	UNPROCESSED
24	48	18	2.4
25.1	0	15.5	NO MATCH
25.2	45	13	3.4
26.1	50	17.5	3.8
26.2	63	15	3.1
27	58	37	4.4
28	51	35	0.2
29.1	51	19.5	4.7
29.2	48	26	4.4
30.1	50	13	5.6
30.2	65	18	7.1

TABLE 5 Modern Alder; results of SORT.STRING analysis

METHOD 1						METHOD 2	METHOD 3
Sample No.	Target 1 (Strings of 13)	Extension 1 (Strings of 10+)	Extension 2 (Strings of 8+)	Extension 3 (Strings of 7+)	Residue (Strings of 6)		
1.1		*				*	
1.2					X		
1.4			*			*	*
2		*				*	
3		*				*	
4.1	*						
4.2			X				*
4.3		*				*	
4.4	*						
5.1		*				*	
5.2	*						
5.4	*						
6			*				*
7				X			
8				X			
9.1	*						
10				*		*	
11				*			*
12					X		*
14	*						
15	*						
16.1		*				*	
16.2							*
17	*						
18.1	*						
18.2	*						
19.2						*	*
20.1		*				*	
20.2	*						
20.3	*						
21.1			*			*	*
21.2	*						
21.3				*			
22							
24					*	*	*
25.2							
26.1							
26.2							
27					X		
28					X	*	*
29.1					X		
29.2							
30.1				*			
30.2							
TOTAL					61%	59%	68%

* Correctly placed

X Incorrectly placed

TABLE 6 Modern Alder; Matrix of z-values

TARGET 1

	4.1	4.4	5.2	5.4	9.1	14	15	17	18.1	18.2	20.2	20.3	21.2
4.1	0												
4.4	4.7	0											
5.2	4.4	4.3	0										
5.4	2.7	3.2	2.8	0									
9.1	2.8	2.8	2.9	2.7	0								
14	5.2	3.9	2.8	2.2	3.1	0							
15	5.1	3.5	5.9	3.9	2.7	3.8	0						
17	3.6	3.7	2.5	2.7	4.1	3.7	3.1	0					
18.1	3.4	2.4	2	2.7	2.6	4.6	3.4	4.4	0				
18.2	3.4	1.9	2.7	2.9	2.3	3	2.8	3	3.6	0			
20.2	3.9	3.3	3.7	3.3	4.2	4.5	4.8	4.9	3.5	3.8	0		
20.3	3.6	2.6	2	2.7	3.9	3.1	3.1	5.6	5.7	2.2	4.6	0	
21.2	3.8	2.7	2.6	3.3	2.4	2.7	3.5	4	3.2	1.7	3.8	5.3	0
EXTENSION 1													
1.1	4.2	4.1	3.5	3.6	-	3.9	3.6	2.2	2.8	3.6	3	-	2.3
3	3.6	3.5	3.2	4	-	3.9	4.4	2.8	2.6	3	3.1	-	3
4.3	5.2	5.3	4.2	2.7	3.1	3.3	3.3	2.8	-	-	2.8	2.7	3.5
5.1	3.1	3.2	4.6	3.2	4.5	-	4.5	2.6	-	-	3.8	2.9	3.4
16.1	3.5	3.2	2.3	-	2.9	3.3	3.1	3.8	4.6	2.4	4.9	4.4	3.7
20.1	2.8	4	1.5	-	2.2	3.2	2	2.1	3.5	2.9	3.7	2.7	2.3
2	2.2	2.8	2.5	-	1.9	2.3	2.6	1.5	-	-	1.9	-	1.4

TABLE 7 Moynagh Lough; Matrix of z-values for SUBPAL2

SUBPAL2

	67	51	57	52	60	50	48	78	59	53	61	79	72
67	0												
51	3	0											
57	3.5	3.5	0										
52	2.7	2.9	-	0									
60	-	-	-	3.9	0								
50	3.5	-	-	1.8	-	0							
48	-	-	-	2.2	-	2.8	0						
78	1.8	-	2.7	-	-	-	3.4	0					
59	1.7	-	-	-	-	-	-	3.3	0				
53	-	2.5	2.3	2	-	2.3	2.9	5	3.1	0			
61	-	-	1.8	-	-	-	2.9	3.9	2.8	3	0		
79	-	4	-	-	-	-	2.8	-	-	-	-	0	
72	-	-	-	3.8	-	-	2.7	-	-	-	3	-	0

SUBPAL2 EXTRAS

	SP2	64	56	62	47	76	63
SP2	0						
64	2.5	0					
56	3	-	0				
62	-	1.7	-	0			
47	-	-	-	2.3	0		
76	-	-	2.7	-	-	0	
63	-	-	1.7	-	-	-	0

TABLE 8 Moynagh Lough; matrices of z-values for sub-masters

SUBPAL2E

	181	183	186
181	0		
183	3	0	
186	3.3	4.5	0

SUBPAL2A

	152	154	155	159
152	0			
154	2.2	0		
155	1.9	-	0	
159	2.9	2.3	2.7	0

CWASH

	91	92	99	100	101
91	0				
92	5.3	0			
99	-	-	0		
100	3	3.5	-	0	
101	-	-	-	2.6	0

CWWILLOW

	33	34	36	42	43	46
33	0					
34	2.6	0				
36	2.5	2.2	0			
42	-	2.8	-	0		
43	3	2.3	-	-	0	
46	-	1.8	-	2.1	2.5	0

SUBPAL3

	124	129	133	142
124	-			
129	-	0		
133	-	-	0	
142	2	-	-	0

TABLE 9 Oakbank; matrices for Blocks 1 - 7

BLOCK 1

	124	384	385	109	179
124	0				
384	-	0			
385	-	3.2	0		
109	-	1.5	3.1	0	
179	3.5	2.6	-	-	0

BLOCK 2

	420	384	387	499	506	179
420	0					
384	3.1	0				
387	2.5	4.9	0			
499	2.3	3	3	0		
506	3.1	-	2	3.8	0	
179	2.9	2.7	4.1	2.2	2.2	0

BLOCK 3

	499	132	349	62
499	0			
132	2.9	0		
349	-	3.6	0	
62	-	-	2.5	0

BLOCK 4

	349	376	379
349	0		
376	2.8	0	
379	-	3	0

BLOCK 5

	386	346	345	420
386	0			
346	3.5	0		
345	-	2.2	0	
420	2.7	1.7	-	0

BLOCK 6

	65	3	471
65	0		
3	3.3	0	
471	2.5	3.1	0

BLOCK 7

	481	30	33	421
481	0			
30	4.1	0		
33	3.7	4.4	0	
421	3.2	6.6	-	0

TABLE 10 Oakbank; matrices for Blocks 9 - 11

BLOCK 9

	589	525	585	523	520	534	522
589	0						
525	3.8	0					
585	-	4.1	0				
523	-	-	2.3	0			
520	-	3.3	4.3	1.6	0		
534	-	-	-	-	-	0	
522	-	2.2	-	-	2.1	2.5	0

BLOCK 10

	520	313	522	309	584	585
520	0					
313	3.6	0				
522	2.1	-	0			
309	2.5	-	1.8	0		
584	2.2	-	1.1	3.2	0	
585	4.3	5.6	-	-	-	0

BLOCK 11

	446	313	308	353	310	408
446	0					
313	3.7	0				
308	3.5	2.6	0			
353	-	2	3.2	0		
310	-	-	2	-	0	
408	2.4	-	4	2.1	-	0

TABLE 11 Oakbank; matrices for Blocks 12 - 13, 15 - 16, 18 -19

BLOCK 12

	548	533	522	550	585
548	0				
533	3.7	0			
522	3.8	2.3	0		
550	2.6	2.7	3.4	0	
585	-	2.3	-	2.9	0

BLOCK 13

	381	459	460	490	511
381	0				
459	2.5	0			
460	1.7	2.9	0		
490	-	-	4.2	0	
511	0	2	2.3	2.2	0

BLOCK 15

	606	616	618
606	0		
616	7.3	0	
618	3.5	5.4	0

BLOCK 16

	604	613	309	600	490	460
604	0					
613	2.7	0				
309	2.4	2.8	0			
600	-	2.2	2.1	0		
490	-	3	1.9	1.8	0	
460	-	4.2	1.2	3.2	4.2	0

BLOCK 18

	X1	X2	X3	X10	X12A
X1	0				
X2	2.4	0			
X3	2.6	-	0		
X10	4.5	-	3.8	0	
X12A	2.6	2.7	-	3	0

BLOCK 19

	X16	X15	X11	X9
X16	0			
X15	2.9	0		
X11	-	4.6	0	
X9	-	3.7	4.1	0

TABLE 12 Oakbank; matrices for Blocks 17 and 7

BLOCK 17

	X23	X36	X29	X34	X35	X20	X24	X22	X25	X38	X21	X13	X6
X23	0												
X36	4.7	0											
X29	4.2	4.9	0										
X34	4.5	4.3	4.2	0									
X35	4.6	4.5	3.9	3.6	0								
X20	3	3.6	3.9	3.2	3.9	0							
X24	-	4.3	3.4	-	-	3.6	0						
X22	-	3.2	2.9	-	-	2.9	3.1	0					
X25	-	3.3	4.6	3.7	2.8	3.5	-	3.2	0				
X38	-	-	1.8	-	-	-	2.1	-	2.8	0			
X21	-	4.3	3.5	-	-	-	-	4.9	3.9	3.2	0		
X13	-	3.1	3.4	-	-	2.7	-	3.1	3.9	2.1	4.1	0	
X6	-	3.6	4.1	3.5	2.2	2.7	-	2	3.6	-	2.6	3.5	0

BLOCKS 7 & 17

	481	30	33	421	X36	X29	X34	X35	X25
481	0								
30	4.1	0							
33	3.7	4.4	0						
421	3.2	6.6	-	0					
X36	5	4.9	5.5	5.8	0				
X29	3.4	3.4	3.5	3	4.9	0			
X34	5.3	4.8	4	2.3	4.3	4.2	0		
X35	-	3.4	5.9	4	4.5	3.9	3.6	0	
X25	2.9	3.3	-	-	3.3	4.6	3.7	2.8	0

TABLE 13   Oakbank; matrix for Hazel

HAZEL

	428	561	564	322
428	0			
561	3.1	0		
564	2.6	2.2	0	
322	-	1.9	3.8	0

TABLE 14 Oakbank; sequences found in both the traditional and SORT.STRING chronologies but in conflicting chronological positions

	Maximum z-value in trad. chron.
384/385	X
62/499	/
62/132	/
522/525	X
522/585	/
522/520	X
522/313	/
446/313	X
446/308	X
310/308	X
310/408	/
550/585	X
511/460	X
511/490	X
511/381	/

TABLE 15 Oakbank; spread of end-years in Blocks 1 - 22

BLOCK NO.	CONTEXTS	SPREAD (in yrs)
1	F1,F2,F3	1___5
2	F1,F4,F6	1________10
3	F5,F6	1______8
4	F4,F6	0
5	G2,F6,F7	1__4
6	F8,F11	1_3
7	F8,F11	1_2
8	F10,F14	1_3
9	F24	1___5 (1 sample felled 18 years late
10	F17,F24,G5	1___________13
11	G1,F17	1____________14
12	F24,G5	1___5
13	G4	1____6
14	G4	1____6
15	G1	1______8
16	G1,G4,F17	1____6
17	G6	1_3 (1 sample felled 13 years later)
18	G6	1_2
19	G6	1_2
20	G6	1_2
21	G6	1_2
21	G6	1_2

APPENDIX 4

TREE-RING DATA

The data presented in this appendix are the composite stem-masters compiled from the several radii measured on each sample (see Chapt.8). The tree-ring sequences for each radius are available from the author or from the Dendrochronology Laboratory, Sheffield University. The data is listed by site, in order of sample number (see Tables 1 and 2).

```
]

ML82
MC1M
47

1     - 72  73  50  57  34  25  28  35  38  45

11    - 42  19  22  17  19  13  24  7   14  32

21    - 21  31  28  53  40  51  30  32  23  33

31    - 30  31  16  33  75  59  98  57  44  34

41    - 33  41  16  24  47  39  58

TREES INCLUDED ARE -  MC1A MC1C

ML82
MC2M
50

1     - 35  51  92  50  43  35  49  32  29  38

11    - 87  85  72  38  11  8   18  11  7   5

21    - 9   26  37  24  52  5   27  45  43  38

31    - 21  17  40  32  36  20  52  54  34  35

41    - 35  42  17  25  13  13  19  15  16  16


TREES INCLUDED ARE -  MC2A MC2B

ML82
MC3M
19

1     - 121 77  78  100 112 67  65  82  108 137

11    - 107 129 126 99  86  47  135 142 64

TREES INCLUDED ARE -  MC3A MC3B MC3C

ML82
MC4M
19

1     - 217 122 110 141 140 89  113 116 146 159

11    - 140 127 123 93  92  55  123 147 68

TREES INCLUDED ARE -  MC4A MC4B MC4C
```

```
7ML82
MC5M
32

1     - 53   66   40   50   48   54   39   38   32   27

11    - 58   34   47   61   88   41   29   35   57   119

21    - 84   75   97   68   64   57   48   88   65   51

31    - 93   48

TREES INCLUDED ARE -  MC5A MC5B MC5C

ML82
MC6M
49

1     - 125 45   35   68   56   88   124  154  46   91

11    - 48   43   83   102  69   50   67   73   48   24

21    - 36   44   19   48   23   32   45   36   9    9

31    - 12   8    4    28   18   3    15   22   23   41

41    - 20   22   19   23   20   5    6    6    10

TREES INCLUDED ARE -  MC6A MC6B MC6C MC6D

ML82
MC7M
32

1     - 148 88   117  113  109  97   77   69   104  78

11    - 63   59   53   78   55   26   25   45   37   66

21    - 79   31   36   65   52   34   33   30   22   60

31    - 69   71

TREES INCLUDED ARE -  MC7A MC7B MC7C MC7D
```

```
ML82
MC9M
30

1     - 16   18   66   48   26   38   24   36   37   25

11    - 26   32   16   22   31   53   39   23   15   16

21    - 29   104  48   115  75   33   26   37   30   36



TREES INCLUDED ARE -  MC9A MC9B MC9C

ML82
MC10M
27

1     - 73   26   26   27   79   104  99   58   117  115

11    - 56   79   77   166  138  94   111  87   86   69

21    - 103  45   92   138  88   59   38

TREES INCLUDED ARE -  MC10A MC10B MC10C

ML82
MC11M
36

1     - 75   168  226  120  140  125  85   61   29   30

11    - 109  46   67   65   44   45   90   49   77   96

21    - 56   25   30   36   36   11   35   44   9    11

31    - 24   30   23   18   30   11

TREES INCLUDED ARE -  MC11A MC11B MC11C


ML82
MC15M
34

1     - 26   100  65   53   38   17   32   41   57   71

11    - 54   84   54   33   22   18   47   33   21   43

21    - 83   53   32   18   29   46   41   41   66   51

31    - 30   15   53   80

TREES INCLUDED ARE -  MC15A MC15B  MC15C
```

```
ML82
MC16M
24

1      - 46  83  138 85  91  71  71  62  42  56

11     - 78  89  72  94  102 74  89  76  78  109

21     - 113 42  61  48

TREES INCLUDED ARE -  MC16A MC16B MC16C

ML82
MC17M
35

1      - 40  83  68  81  40  39  25  22  14  19

11     - 10  11  7   8   13  33  55  32  28  32

21     - 14  6   8   6   10  14  9   7   15  15

31     - 37  27  2   4   11

TREES INCLUDED ARE -  MC17A MC17B

ML82
MC18M
17

1      - 48  43  30  95  89  155 171 59  79  115

11     - 62  109 60  51  146 62  15

TREES INCLUDED ARE -  MC18A MC18B MC18C

ML82
MC19M
25

1      - 77  107 21  30  13  25  21  23  18  14

11     - 44  20  25  34  13  12  16  14  28  38

21     - 45  62  31  38  44

TREES INCLUDED ARE -  MC19A MC19B MC19C
```

```
ML82
MC20M
48

1    - 142 70  55  47  67  51  63  96  109 92

11   - 94  22  21  32  19  15  16  6   19  34

21   - 37  38  19  34  51  53  36  16  25  27

31   - 28  12  5   8   15  12  14  13  17  17

41   - 16  4   2   9   8   3   4   10

TREES INCLUDED ARE -  MC20A MC20B MC20C

ML82
MC24M
25

1    - 58  90  110 149 110 84  74  56  44  146

11   - 183 196 155 95  51  35  32  23  32  34

21   - 33  31  21  23  23

TREES INCLUDED ARE -  MC24A MC24B MC24C

ML82
MC27M
17

1    - 45  71  48  23  54  74  50  108 46  49

11   - 68  67  62  70  60  54  42

TREES INCLUDED ARE -  MC27A MC27B

ML82
MC30M
20

1    - 14  130 45  25  56  58  84  101 91  94

11   - 70  45  47  41  60  103 96  124 88  116



TREES INCLUDED ARE -  MC30A MC30B MC30C
```

```
ML82
MC31M
24

1     - 64   128 117 103 72   108 112 111 74   83

11    - 77   41   61   28   77   112 113 123 151 84

21    - 99   77   72   18

TREES  INCLUDED  ARE  -   MC31A  MC31B  MC31C


ML82
MC32M
17

1     - 73   18   79   69   89   63   111  107 91   83

11    - 67   89   57   97   72   110 71

TREES  INCLUDED  ARE  -   MC32A  MC32B  MC32C


ML82
MC33M
26

1     - 36   48   42   55   17   27   29   15   14   25

11    - 29   43   33   31   31   32   59   90   56   78

21    - 58   48   36   33   40   51

TREES  INCLUDED  ARE  -   MC33A  MC33B  MC33C


ML82
MC34M
19

1     - 57   67   92   111  97   76   83   43   35   58

11    - 97   54   47   47   41   47   29   33   35

TREES  INCLUDED  ARE  -   MC34A  MC34B  MC34C


ML82
MC36M
30

1     - 64   40   47   68   69   75   51   40   22   19

11    - 24   12   18   26   17   21   14   26   19   15

21    - 20   29   19   17   9    19   22   15   23   20



TREES  INCLUDED  ARE  -   MC36A  MC36B  MC36C
```

```
ML82
MC37M
32

1     - 80   116  123  52   79   22   24   48   81   123

11    - 90   107  128  107  133  85   58   54   52   48

21    - 77   54   75   54   48   46   56   29   81   51

31    - 43   51

TREES INCLUDED ARE -  MC37A MC37B MC37C

ML82
MC38M
31

1     - 171  200  93   120  26   14   17   57   139  79

11    - 90   58   70   74   54   30   26   40   67   89

21    - 59   96   59   34   22   115  48   88   67   114

31    - 177

TREES INCLUDED ARE -  MC38A MC38B MC38C

ML82
MC39M
45

1     - 44   16   9    12   14   27   21   12   15   13

11    - 57   18   12   16   10   13   21   19   14   19

21    - 23   13   28   20   19   13   17   14   17   33

31    - 52   31   12   32   20   12   14   18   12   19

41    - 52   29   29   12   40

TREES INCLUDED ARE -  MC39A MC39B

ML82
MC42M
23

1     - 31   130  121  80   46   79   42   46   54   53

11    - 76   33   36   43   70   47   42   42   42   39

21    - 24   31   33

TREES INCLUDED ARE -  MC42A MC42B MC42C
```

```
ML82
MC43M
25

1     - 64   98   71   19   34   22   19   28   20   37

11    - 90   85   93   59   50   74   89   58   52   51

21    - 43   44   30   29   32

TREES INCLUDED ARE -  MC43A MC43B MC43C

ML82
MC44M
32

1     - 62   18   20   92   59   107  52   28   27   61

11    - 121  117  65   104  86   87   31   51   28   27

21    - 28   18   31   77   52   15   15   24   17   43

31    - 40   52

TREES INCLUDED ARE -  MC44A MC44B MC44C

ML82
MC45M
28

1     - 61   33   70   49   53   132  184  134  92   75

11    - 60   88   83   137  85   83   66   56   47   42

21    - 57   54   57   45   20   12   12   13

TREES INCLUDED ARE -  MC45A MC45B MC45C MC45D

ML82
MC46M
23

1     - 84   75   55   52   41   47   32   43   69   63

11    - 89   45   38   48   62   50   49   52   39   33

21    - 38   31   37

TREES INCLUDED ARE -  MC46A MC46B MC46C
```

```
MC82
MC47M
23

1     - 144 140 85  118 145 121 158 182 191 177

11    - 124 77  27  22  14  29  78  79  114 50

21    - 21  27  27

TREES INCLUDED ARE -  MC47A MC47B MC47C

MC82
MC48M
35

1     - 122 31  107 68  28  20  37  46  50  85

11    - 98  78  70  100 92  121 89  63  159 144

21    - 168 124 99  117 71  35  62  77  97  67

31    - 73  84  45  24  41

TREES INCLUDED ARE -  MC48A MC48B MC48C

ML82
MC50M
33

1     - 30  15  21  9   16  50  60  82  72  74

11    - 80  92  100 110 90  69  74  75  137 93

21    - 87  103 81  68  57  56  86  66  81  81

31    - 85  36  48

TREES INCLUDED ARE -  MC50A MC50B MC50C

MC82
MC51M
39

1     - 0   63  33  55  23  24  27  31  27  28

11    - 34  36  66  71  73  40  44  72  90  78

21    - 101 66  82  57  76  57  57  60  30  46

31    - 52  37  66  50  39  45  34  10  10

TREES INCLUDED ARE -  MC51A MC51B
```

```
ML82
MC43M
25

1    - 64  98  71  19  34  22  19  28  20  37

11   - 90  85  93  59  50  74  89  58  52  51

21   - 43  44  30  29  32

TREES INCLUDED ARE -  MC43A MC43B MC43C

ML82
MC44M
32

1    - 62  18  20  92  59  107 52  28  27  61

11   - 121 117 65  104 86  87  31  51  28  27

21   - 28  18  31  77  52  15  15  24  17  43

31   - 40  52

TREES INCLUDED ARE -  MC44A MC44B MC44C

ML82
MC45M
28

1    - 61  33  70  49  53  132 184 134 92  75

11   - 60  88  83  137 85  83  66  56  47  42

21   - 57  54  57  45  20  12  12  13

TREES INCLUDED ARE -  MC45A MC45B MC45C MC45D

ML82
MC46M
23

1    - 84  75  55  52  41  47  32  43  69  63

11   - 89  45  38  48  62  50  49  52  39  33

21   - 38  31  37

TREES INCLUDED ARE -  MC46A MC46B MC46C
```

MC82
MC56M

```
26

1     - 106 63   18   92   103 51   44   53   64   77

11    - 71   62   67   74   106 78   66   69   88   113

21    - 111 83   94   77   43   43

TREES INCLUDED ARE -  MC56A MC56B MC56C
```

ML82
MC57M

```
29

1     - 99   36   65   50   56   51   93   136 96   91

11    - 85   48   79   75   103 70   50   67   39   56

21    - 42   33   63   49   67   42   26   12   13

TREES INCLUDED ARE -  MC57A MC57B MC57C
```

ML82
MC59M

```
38

1     - 24   16   17   24   32   16   32   20   24   17

11    - 27   17   42   53   52   98   115 100 74   88

21    - 85   106 111 140 117 95   139 45   11   17

31    - 71   97   94   132 126 103 36   61

TREES INCLUDED ARE -  MC59A MC59B MC59C
```

ML82
MC60M

```
36

1     - 0    50   53   44   44   30   45   46   99   105

11    - 124 105 58   80   132 111 104 117 97   144

21    - 113 71   65   52   57   35   77   61   56   69

31    - 58   38   33   38   15   7

TREES INCLUDED ARE -  MC60A MC60B MC60C MC60D
```

```
MC82
MC61M
29

1     - 61  66  101 97  91  74  91  136 129 143

11    - 137 111 118 104 112 94  88  100 54  32

21    - 31  62  74  44  52  63  25  19  10

TREES INCLUDED ARE -  MC61A  MC61B MC61C

ML82
MC62M
23

1     - 73  42  57  101 133 125 135 149 151 149

11    - 110 153 90  33  54  79  113 105 92  54

21    - 28  28  43

TREES INCLUDED ARE -  MC62A MC62B MC62C

ML82
MC63M
25

1     - 156 176 258 198 135 121 102 83  60  63

11    - 79  64  93  120 105 104 82  93  158 125

21    - 100 86  64  47  73

TREES INCLUDED ARE -  MC63A MC63B

MC82
MC64M
26

1     - 58  58  78  53  76  79  63  70  116 137

11    - 121 142 150 126 128 79  57  62  71  84

21    - 88  114 94  69  36  68

TREES INCLUDED ARE -  MC64A MC64B MC64C
```

```
ML82
MC65M
35

1      - 78   31   40   34   30   87   35   52   91   67

11     - 39   28   46   41   42   46   48   119  98   93

21     - 117  126  109  73   110  68   105  106  88   67

31     - 46   45   17   6    10

TREES INCLUDED ARE -  MC65A MC65B MC65C

ML82
MC66
70

1      - 17   26   88   78   52   50   48   46   52   55

11     - 52   42   38   40   63   59   65   74   45   43

21     - 48   53   67   51   44   39   23   29   23   22

31     - 25   38   34   28   23   26   30   23   17   19

41     - 17   20   66   64   112  155  111  170  224  110

51     - 102  162  161  204  91   67   64   44   60   50

61     - 44   61   27   27   17   23   21   24   17   17




MC82
MC67M
22

1      - 77   89   98   114  126  127  122  198  138  132

11     - 139  57   73   49   56   85   53   67   46   40

21     - 25   25

TREES INCLUDED ARE -  MC67A MC67B
```

```
ML82
MC68M
27

1     - 97  17  49  19  22  30  27  18  11  58

11    - 107 83  63  60  55  63  54  63  70  102

21    - 143 142 130 100 84  66  42

TREES INCLUDED ARE -  MC68A MC68B MC68C

MC82
MC70M
22

1     - 110 63  83  102 138 99  104 86  54  42

11    - 39  49  63  63  99  160 144 172 162 152

21    - 94  85

TREES INCLUDED ARE -  MC70B MC70C

ML82
MC71M
33

1     - 67  21  6   5   15  17  14  15  41  24

11    - 55  77  66  71  79  77  117 108 90  103

21    - 90  129 87  105 88  80  124 145 156 74

31    - 79  41  34

TREES INCLUDED ARE -  MC71A MC71B MC71C MC71D

MC82
MC72M
36

1     - 0   32  11  16  8   17  14  24  32  50

11    - 85  74  46  51  76  97  77  56  66  103

21    - 102 89  96  84  83  71  71  68  79  95

31    - 83  75  46  23  22  13

TREES INCLUDED ARE -  MC72A MC72B MC72C
```

```
MC82
MC73M
29

1    - 0   35  68  63  24  24  50  81  62  65

11   - 59  56  75  77  91  67  58  80  54  65

21   - 75  61  60  62  80  61  69  34  55

TREES INCLUDED ARE -  MC73A MC73B MC73C

MC82
MC74M
26

1    - 153 93  64  81  84  83  75  73  70  84

11   - 84  62  53  61  82  44  70  70  78  95

21   - 97  106 41  74  25  46

TREES INCLUDED ARE -  MC74A MC74B MC74C

ML82
MC75M
21

1    - 35  60  97  60  81  116 158 137 119 169

11   - 97  73  70  105 130 72  144 123 73  37

21   - 43

TREES INCLUDED ARE -  MC75A MC75B MC75C

MC82
MC76M
23

1    - 31  96  119 104 135 129 149 125 105 100

11   - 92  68  49  49  30  38  57  43  20  33

21   - 28  21  14

TREES INCLUDED ARE -  MC76A MC76B MC76C
```

```
ML82
MC77M
21

1     - 118 94   88   112 123 118 117 113 131 135

11    - 99   43   32   57   83   127 111 125 74   90

21    - 62

TREES INCLUDED ARE -  MC77A MC77B MC77C


MC82
MC78M
36

1     - 104 56   18   6    30   12   12   10   12   19

11    - 16   31   24   49   108 119 125 117 113 144

21    - 136 127 117 94   111 75   35   50   69   125

31    - 92   89   73   50   20   18

TREES INCLUDED ARE -  MC78A MC78B MC78C


ML82
MC79M
46

1     - 0    4    5    6    4    6    2    10   3    19

11    - 13   11   28   11   10   10   9    18   32   48

21    - 83   74   70   78   96   90   93   81   85   82

31    - 91   101 94   71   61   41   32   32   45   64

41    - 35   27   19   13   15   13

TREES INCLUDED ARE -  MC79A MC79B MC79C MC79D


ML82
MC80M
22

1     - 14   94   72   49   67   101 55   44   91   100

11    - 90   56   53   111 125 175 105 28   124 106

21    - 73   87

TREES INCLUDED ARE -  MC80A MC80B MC80C
```

```
MC82
MC81M
22

1     - 114 160 86  55  72  62  72  129 172 84

11    - 104 98  74  116 130 172 154 122 207 165

21    - 93  105

TREES INCLUDED ARE -  MC81A MC81B MC81C

ML82
MC82M
37

1     - 192 82  65  95  87  56  71  107 121 98

11    - 132 96  70  55  50  37  40  28  19  20

21    - 15  9   17  12  11  9   9   15  11  11

31    - 14  9   12  14  13  10  14

TREES INCLUDED ARE -  MC82A MC82B MC82C

ML82
MC84M
40

1     - 30  65  65  83  59  44  38  45  66  103

11    - 57  63  46  23  22  92  16  31  45  20

21    - 26  22  19  20  15  43  26  24  64  20

31    - 24  18  19  20  18  18  38  21  23  22


TREES INCLUDED ARE -  MC84A MC84B MC84C

ML82
MC85M
19

1     - 85  67  19  28  29  16  18  60  99  120

11    - 116 104 77  91  120 108 126 116 140

TREES INCLUDED ARE -  MC85A MC85B MC85C
```

```
ML82
MC87M
17

1     - 67   115 78   60   90   67   67   75   65   46

11    - 75   71   75   64   62   65   72

TREES INCLUDED ARE -  MC87A MC87B MC87C

ML82
MC88M
17

1     - 41   94   122 109 92   133 104 68   82   70

11    - 98   60   68   63   58   75   57

TREES INCLUDED ARE -  MC88A MC88B MC88C

ML82
MC90M
23

1     - 0    60   109 121 102 165 199 138 99   117

11    - 154 150 138 107 120 147 143 184 176 167

21    - 242 220 153

TREES INCLUDED ARE -  MC90A MC90B

ML82
MC91M
32

1     - 68   57   69   71   42   35   31   36   27   27

11    - 51   49   41   40   42   38   44   57   47   49

21    - 63   75   59   72   55   50   71   73   67   48

31    - 74   54

TREES INCLUDED ARE -  MC91A  MC91B MC91C
```

```
ML82
MC92M
32

1     - 49   34   83   67   39   37   28   35   39   24

11    - 69   55   43   37   39   31   45   54   54   59

21    - 56   79   51   64   42   55   64   69   60   47

31    - 69   48

TREES INCLUDED ARE -  MC92A MC92B MC92C

ML82
MC93M
23

1     - 110  44   98   94   58   58   36   44   53   126

11    - 100  102  84   139  68   91   113  107  101  65

21    - 53   101  66

TREES INCLUDED ARE -  MC93A MC93B MC93C

ML82
MC94M
35

1     - 56   55   18   25   17   24   71   138  107  67

11    - 84   19   11   7    13   36   15   16   11   23

21    - 36   37   29   45   44   26   69   27   37   56

31    - 54   45   28   58   91

TREES INCLUDED ARE -  MC94A MC94B

ML82
MC95M
23

1     - 79   57   40   22   32   52   63   49   33   52

11    - 22   13   11   26   29   17   18   25   52   39

21    - 53   38   19

TREES INCLUDED ARE -  MC95A MC95B MC95C
```

```
ML82
MC97M
23

1     - 25  42  25  58  41  14  56  52  37  21

11    - 56  136 145 118 112 79  65  45  61  81

21    - 64  76  36


TREES INCLUDED ARE -  MC97A MC97B MC97C


ML82
MC98M
21

1     - 15  56  46  58  53  53  47  70  93  88

11    - 104 88  73  62  83  92  90  64  63  61

21    - 73


TREES INCLUDED ARE -  MC98A MC98B MC98C


ML82
MC99M
61

1     - 28  37  50  46  32  36  22  24  33  20

11    - 40  31  18  12  15  16  13  13  13  18

21    - 29  34  34  35  35  25  19  17  12  13

31    - 22  15  35  26  26  18  13  19  13  11

41    - 15  26  17  21  10  11  15  21  18  17

51    - 34  11  12  13  10  12  15  15  17  12

61    - 18


TREES INCLUDED ARE -  MC99A MC99B MC99C


ML82
MC100M
31

1     - 65  110 54  34  24  26  35  34  17  42

11    - 60  46  51  44  56  47  40  33  51  52

21    - 56  55  36  47  83  107 125 107 60  183

31    - 144


TREES INCLUDED ARE -  MC100A MC100B MC100C
```

ML82
MC101M

```
41

1     - 39   84   16   50   66   30   9    6    27   19

11    - 62   51   56   62   40   43   26   42   14   35

21    - 53   41   49   44   46   58   68   68   62   63

31    - 73   70   85   71   65   87   92   74   51   71

41    - 49

TREES INCLUDED ARE -  MC101A MC101B MC101C
```

ML82
MC102M

```
33

1     - 106 81   43   57   65   52   58   42   59   50

11    - 73   44   50   38   36   48   55   55   44   65

21    - 83   84   61   66   57   44   27   36   42   38

31    - 49   48   41

TREES INCLUDED ARE -  MC102A MC102B MC102C
```

ML82
MC103M

```
33

1     - 117 11   66   50   34   92   96   66   69   56

11    - 41   85   102 84   83   62   60   47   28   27

21    - 40   48   53   36   39   21   20   18   17   17

31    - 17   25   17

TREES INCLUDED ARE -  MC103A MC103B MC103C MC103D
```

ML82
MC104M

```
31

1     - 51   118 90   48   30   12   25   9    11   82

11    - 62   50   37   51   16   23   23   56   81   83

21    - 74   133 73   72   145 125 147 79   49   170

31    - 91

TREES INCLUDED ARE -  MC104A MC104B
```

```
ML82
MC105M
52

1     - 150 157 89  58  39  72  156 83  58  12

11    - 24  26  120 88  76  38  86  105 56  35

21    - 44  63  11  9   7   9   37  73  64  24

31    - 21  7   5   1   4   2   2   5   4   4

41    - 7   2   3   3   8   2   3   9   4   3

51    - 2   14

TREES INCLUDED ARE -  MC105A MC105B

ML82
MC106M
48

1     - 94  79  76  54  35  25  22  43  65  90

11    - 99  47  42  41  34  25  20  23  24  25

21    - 27  23  26  18  27  20  21  23  23  24

31    - 39  23  27  24  25  21  23  29  23  25

41    - 19  17  21  19  21  20  18  18

TREES INCLUDED ARE -  MC106A MC106B

ML82
MC107M
55

1     - 26  57  36  20  30  15  10  37  56  47

11    - 59  33  21  19  29  54  64  66  48  34

21    - 56  25  22  18  18  21  15  16  27  20

31    - 25  16  17  17  15  18  20  29  26  25

41    - 40  20  19  21  20  18  22  19  17  16

51    - 23  22  20  19  17

TREES INCLUDED ARE -  MC107A MC107B MC107C
```

```
ML82
MC110M
34

1     - 20   74   33   19   12   13   12   26   29   26

11    - 62   76   117  106  72   75   53   77   75   55

21    - 78   60   56   46   27   36   30   45   43   79

31    - 95   76   73   86

TREES INCLUDED ARE -  MC110A MC110B




ML82
MC111
39

1     - 101  29   19   18   25   24   55   26   12   11

11    - 10   12   9    10   11   12   11   17   69   73

21    - 249  384  282  148  145  74   44   74   81   89

31    - 133  113  123  67   102  108  135  81   266




ML82
MC112
15

1     - 0    358  321  252  364  260  321  321  322  272

11    - 200  195  186  178  143




ML82
MC114M
21

1     - 115  88   56   67   89   81   79   109  99   140

11    - 83   67   73   69   67   64   39   63   66   44

21    - 47

TREES INCLUDED ARE -  MC114A MC114B
```

```
ML82
MC116M
21

1     - 24  119 79  71  34  38  49  59  86  57

11    - 108 57  33  23  20  16  31  26  17  31

21    - 26

TREES INCLUDED ARE -  MC116A MC116B MC116C

ML82
MC119M
28

1     - 27  100 78  55  64  55  70  61  64  52

11    - 76  53  51  36  30  18  39  20  14  9

21    - 16  12  9   16  14  26  22  17

TREES INCLUDED ARE -  MC119A MC119B MC119C

ML82
MC120M
17

1     - 36  39  41  52  52  42  48  79  31  32

11    - 38  26  39  38  24  30  46

TREES INCLUDED ARE -  MC120A MC120B

ML82
MC122M
25

1     - 32  49  37  29  37  45  52  66  62  58

11    - 91  45  61  77  73  44  87  63  90  87

21    - 133 141 92  108 126

TREES INCLUDED ARE -  MC122A MC122B

ML82
MC123M
29

1     - 27  35  35  37  25  23  33  15  23  26

11    - 33  19  31  33  33  36  51  72  77  59

21    - 120 71  76  57  64  62  53  84  83

TREES INCLUDED ARE -  MC123A MC123B
```

```
ML82
MC124M
18

1     - 165 140 61  66  66  68  77  97  53  85

11    - 111 120 101 116 118 79  104 108

TREES INCLUDED ARE -  MC124A MC124B

ML82
MC125M
31

1     - 171 81  77  67  102 56  47  46  51  43

11    - 55  44  54  42  36  35  37  28  17  33

21    - 37  31  17  17  24  29  39  23  26  29

31    - 25

TREES INCLUDED ARE -  MC125A MC125C

ML82
MC126M
18

1     - 28  76  91  55  61  47  49  42  64  68

11    - 78  55  30  24  38  83  88  100

TREES INCLUDED ARE -  MC126A MC126B

ML82
MC129M
21

1     - 49  90  28  55  60  54  63  43  31  27

11    - 66  51  27  45  48  55  44  48  46  32

21    - 40

TREES INCLUDED ARE -  MC129A MC129B
```

```
ML82
MC130M
26

1     - 43   69   66   34   54   66   64   39   40   47

11    - 49   27   38   43   51   53   54   34   32   35

21    - 54   35   35   41   43   43

TREES INCLUDED ARE -  MC130A MC130B

ML82
MC131M
18

1     - 66   85   83   99   98   94   130  142  154  165

11    - 172  125  57   24   20   52   67   39

TREES INCLUDED ARE -  MC131A MC131B

ML82
MC132M
19

1     - 47   28   17   49   49   35   34   58   103  82

11    - 101  100  55   84   101  86   93   83   92

TREES INCLUDED ARE -  MC132A MC132B

ML82
MC133M
20

1     - 145  125  127  106  77   99   48   63   79   83

11    - 116  61   79   69   68   61   72   98   74   74



TREES INCLUDED ARE -  MC133A MC133B

ML82
MC134M
22

1     - 13   33   27   30   22   18   29   48   62   30

11    - 77   78   103  85   112  93   148  128  131  136

21    - 154  141

TREES INCLUDED ARE -  MC134A MC134C
```

```
ML82
MC135M
30

1     - 110 46   90   70   22   46   47   98   120 87

11    - 70   83   57   42   76   79   21   30   10   20

21    - 40   27   18   30   39   15   33   35   27   30


TREES INCLUDED ARE -  MC135B MC135C


ML82
MC138M
15

1     - 134 150 194 326 213 136 140 102 165 146

11    - 107 151 196 154 159

TREES INCLUDED ARE -  MC138A MC138B

ML82
MC139M
20

1     - 0    4    16   12   8    28   59   92   154 150

11    - 175 153 104 97   115 116 138 140 191 174


TREES INCLUDED ARE -  MC139A MC139B

ML82
MC140M
16

1     - 34   41   82   128 108 112 159 75   81   48

11    - 108 72   117 120 130 135

TREES INCLUDED ARE -  MC140A MC140B
```

```
ML82
MC141M
22

1     - 61   14   29   79   64   57   26   15   21   11

11    - 29   73   83   134  149  200  168  199  196  211

21    - 281  285

TREES INCLUDED ARE -   MC141A MC141B

ML82
MC142M
19

1     - 71   73   92   72   31   33   49   25   77   68

11    - 50   77   47   39   35   49   62   50   57

TREES INCLUDED ARE -   MC142A MC142B


ML82
MC143
28

1     - 75   112  102  25   32   73   72   67   70   95

11    - 88   80   73   87   80   71   63   60   107  91

21    - 118  92   102  87   115  122  102  108



ML82
MC144M
21

1     - 40   115  116  146  134  85   91   63   76   56

11    - 67   52   44   47   37   49   47   35   32   36

21    - 44

TREES INCLUDED ARE -   MC144A MC144B
```

```
ML82
MC145M
22

1     - 25   45   36   42   44   66   56   44   36   17

11    - 68   66   83   143  138  207  185  175  185  149

21    - 158  165

TREES INCLUDED ARE -  MC145A MC145B MC145C

ML82
MC147M
30

1     - 24   90   73   31   58   37   32   73   48   92

11    - 65   56   55   39   36   11   6    9    8    20

21    - 33   12   8    7    6    8    17   25   11   50



TREES INCLUDED ARE -  MC147A MC147B MC147C

ML82
MC151M
24

1     - 99   261  189  141  160  195  181  149  139  208

11    - 118  74   81   82   139  140  181  122  98   158

21    - 140  61   108  191

TREES INCLUDED ARE -  MC151A MC151B

ML82
MC152M
20

1     - 152  161  122  55   74   85   99   103  88   65

11    - 48   54   45   33   55   22   17   35   30   28



TREES INCLUDED ARE -  MC152A MC152B
```

```
ML82
MC153M
43

1     - 43  93   44   43   63   49   24   22   36   35

11    - 39  25   25   13   13   28   34   45   44   27

21    - 53  22   11   20   18   6    8    9    13   9

31    - 22  11   8    6    8    10   16   35   42   38

41    - 62  41   43

TREES INCLUDED ARE -  MC153A MC153B

ML82
MC154M
21

1     - 52  116 66   66   54   89   86   74   86   85

11    - 88  46   45   49   44   73   61   48   61   64

21    - 47

TREES INCLUDED ARE -  MC154A MC154B

ML82
MC155M
20

1     - 80  146 108 76   103 103 69   100 77   66

11    - 59  35   20   18   41   25   29   25   35   26



TREES INCLUDED ARE -  MC155A MC155B

ML82
MC157M
43

1     - 22  35   18   39   47   39   21   11   18   14

11    - 32  7    15   8    8    22   15   9    30   35

21    - 24  13   16   48   60   47   28   32   42   25

31    - 44  19   16   18   16   26   21   12   42   45

41    - 39  42   36

TREES INCLUDED ARE -  MC157A MC157B
```

```
ML82
MC159M
29

1     - 43  96  55  42  39  29  47  65  42  22

11    - 25  48  40  62  51  25  17  19  17  26

21    - 82  74  51  79  87  52  126 126 124


TREES INCLUDED ARE -  MC159A MC159B


ML82
MC161M
26

1     - 45  114 82  40  48  38  53  51  34  63

11    - 87  34  38  35  38  38  47  32  52  73

21    - 38  18  14  13  26  39


TREES INCLUDED ARE -  MC161A MC161B


ML82
MC162M
19

1     - 70  102 146 76  52  52  57  75  62  65

11    - 59  69  85  68  77  61  80  70  86


TREES INCLUDED ARE -  MC162A MC162B


ML82
MC164M
16

1     - 67  228 220 172 144 118 53  32  40  27

11    - 38  21  31  42  83  67


TREES INCLUDED ARE -  MC164A MC164B


ML82
MC165M
23

1     - 123 49  54  82  65  69  81  77  79  80

11    - 77  56  53  66  40  63  33  66  60  72

21    - 59  64  59


TREES INCLUDED ARE -  MC165A MC165B MC165C
```

```
ML82
MC166M
24

1     - 72   62   75   90   132  114  153  119  104  94

11    - 97   65   77   62   64   64   78   66   70   41

21    - 23   16   15   12


TREES INCLUDED ARE -   MC166A MC166B


ML82
MC167M
22

1     - 51   81   65   73   21   15   12   25   39   59

11    - 85   69   74   85   37   132  122  31   56   136

21    - 175  216


TREES INCLUDED ARE -   MC167A MC167B


ML82
MC168M
21

1     - 95   203  100  84   98   95   89   64   61   49

11    - 74   67   41   25   31   32   21   33   26   46

21    - 56


TREES INCLUDED ARE -   MC168A MC168B


ML82
MC169M
18

1     - 47   60   129  120  121  135  147  124  112  113

11    - 144  175  153  106  128  120  104  106


TREES INCLUDED ARE -   MC169A MC169B


ML82
MC172M
20

1     - 77   53   35   94   162  183  127  88   100  94

11    - 112  108  40   134  111  44   81   174  209  249



TREES INCLUDED ARE -   MC172A MC172B
```

```
ML82
MC173M
19

1     - 99   17   86   142 94   76   35   43   51   41

11    - 58   41   28   22   31   26   34   26   32

TREES INCLUDED ARE -  MC173A MC173B

ML82
MC176M
16

1     - 53   180  120  148  96   93   115  86   82   90

11    - 161  93   108  105  92   83

TREES INCLUDED ARE -  MC176A MC176B

ML82
MC177M
46

1     - 54   75   126  161  212  174  121  171  153  132

11    - 130  64   48   65   68   48   36   51   55   45

21    - 62   39   31   23   22   18   22   15   26   21

31    - 18   10   11   11   10   10   11   9    10   9

41    - 12   10   12   7    6    11

TREES INCLUDED ARE -  MC177A MC177B

ML82
MC179M
19

1     - 49   176  79   59   24   31   27   55   73   66

11    - 79   84   70   69   48   42   33   32   33

TREES INCLUDED ARE -  MC179A MC179B
```

```
ML82
MC180M
23

1     - 24  46  100 122 120 110 83  48  31  30

11    - 183 139 134 80  43  40  74  71  49  71

21    - 114 68  66

TREES INCLUDED ARE -  MC180A MC180B

ML82
MC181M
16

1     - 44  107 143 134 84  102 79  45  66  113

11    - 116 83  74  61  54  68

TREES INCLUDED ARE -  MC181A MC181B

ML82
MC182M
30

1     - 134 91  107 119 135 158 101 103 75  55

11    - 78  48  30  22  16  11  14  9   9   10

21    - 7   5   9   15  32  22  27  35  37  34



TREES INCLUDED ARE -  MC182A MC182B MC182C

ML82
MC183M
23

1     - 54  40  62  48  59  65  36  33  87  77

11    - 109 92  99  63  57  77  84  62  55  48

21    - 43  40  67

TREES INCLUDED ARE -  MC183A MC183B

ML82
MC184M
19

1     - 59  107 149 88  59  55  60  69  68  45

11    - 82  66  73  39  33  25  45  38  59

TREES INCLUDED ARE -  MC184A MC184B
```

```
ML82
MC185M
19

1     - 65   64   35   29   69   66   75   76   62   68

11    - 71   44   33   43   46   42   47   47   59

TREES INCLUDED ARE -  MC185A MC185B

ML82
MC186M
23

1     - 64   52   46   40   64   51   43   33   87   96

11    - 119  84   101  67   54   72   78   49   47   57

21    - 40   48   69

TREES INCLUDED ARE -  MC186A MC186B

ML82
MC187M
17

1     - 85   86   102  67   45   127  105  110  105  111

11    - 123  44   76   58   31   51   36

TREES INCLUDED ARE -  MC187A MC187B



ML85
MC188
75

1     - 351  82   174  182  83   145  143  43   32   199

11    - 117  108  226  368  110  144  167  148  77   43

21    - 100  33   36   38   106  205  58   60   66   59

31    - 75   57   138  60   25   31   29   28   37   14

41    - 27   23   11   22   13   21   18   18   24   30

51    - 45   21   34   43   32   24   36   30   19   42

61    - 67   105  110  38   89   79   61   48   80   58

71    - 90   103  67   83   91
```

```
MC189
40

1     - 101 78  105 187 100 88  351 213 143 101

11    - 170 96  63  134 158 121 208 183 138 300

21    - 132 150 179 114 121 142 68  118 168 76

31    - 84  163 219 69  77  107 81  136 118 121




ML82
MC190M
42

1     - 185 163 109 67  27  18  15  18  28  33

11    - 37  24  38  36  35  34  55  34  46  67

21    - 89  71  55  57  57  71  52  58  54  70

31    - 97  35  38  44  66  46  63  72  74  107

41    - 118 84

TREES INCLUDED ARE -  MC190B MC190A


ML82
MC191
40

1     - 180 107 166 201 207 272 166 131 170 133

11    - 219 190 123 189 198 163 224 164 159 101

21    - 78  77  117 153 73  92  77  62  103 60

31    - 95  51  97  66  69  74  76  72  51  52
```

```
ML82
MC192
29

1     - 43  32  55  36  41  36  32  31  95  130

11    - 113 96  61  59  56  94  112 84  97  75

21    - 92  122 95  87  72  116 96  63  58



ML82
MC193
28

1     - 177 159 188 137 188 207 164 133 169 158

11    - 176 106 244 292 134 164 156 178 173 143

21    - 169 121 129 109 91  70  82  62



ML82
MC194
65

1     - 29  24  36  39  36  44  59  41  74  59

11    - 64  66  63  48  44  72  77  99  75  60

21    - 34  21  18  25  17  22  24  33  53  93

31    - 82  44  29  34  22  21  33  38  34  59

41    - 64  46  43  43  49  118 159 140 88  135

51    - 183 126 99  109 55  59  86  118 101 144

61    - 146 76  57  65  66



ML82
MC195
22

1     - 80  112 131 97  91  151 130 181 174 165

11    - 164 124 183 122 161 140 176 109 155 150

21    - 129 145
```

```
ML82
MC196
139

1     - 75  112 85  112 71  111 79  75  117 100

11    - 96  70  55  89  81  62  79  98  89  74

21    - 109 124 87  87  85  93  96  102 106 107

31    - 77  100 99  110 56  123 69  90  58  94

41    - 90  54  90  48  65  55  27  81  56  106

51    - 105 68  84  82  67  65  63  74  66  74

61    - 60  81  52  66  65  105 106 66  102 65

71    - 65  82  101 103 83  72  84  93  120 88

81    - 76  58  75  92  91  59  97  83  61  68

91    - 76  139 106 112 114 127 115 87  172 85

101   - 147 76  114 93  73  82  71  76  60  73

111   - 70  79  55  67  72  64  54  65  70  50

121   - 58  43  70  59  40  73  37  44  55  58

131   - 56  65  62  97  53  76  58  69  75
```

```
ML82
MC242
108

1     - 120 78  69  91  113 60  77  89  93  111

11    - 121 112 104 78  107 86  105 46  161 86

21    - 71  58  103 83  40  84  39  53  66  40

31    - 62  48  110 101 52  81  124 69  76  63

41    - 64  55  63  54  75  61  74  75  90  156

51    - 69  86  51  57  73  117 91  74  69  81

61    - 101 122 61  62  43  56  100 75  43  106

71    - 57  36  47  77  125 94  122 99  120 132

81    - 68  131 67  190 59  102 87  50  53  74

91    - 86  59  58  47  68  47  66  62  53  57

101   - 65  63  37  67  60  73  83  50
```

```
OC81
OC3M
46

1     - 199 148 156 129 64  73  102 119 164 152

11    - 169 139 100 142 123 136 101 76  66  48

21    - 93  87  60  76 .83  67  50  32  23  18

31    - 21  10  8   16  28  19  23  16  30  18

41    - 56  52  72  57  70  64

TREES INCLUDED ARE -  OC3A OC3B OC3C


OC81
OC15M
23

1     - 241 195 239 162 150 124 64  132 120 136

11    - 192 199 176 156 120 136 136 162 125 143

21    - 160 136 129

TREES INCLUDED ARE -  OC15A OC15B OC15C

OC81
OC30M
23

1     - 0   77  125 148 137 184 145 134 65  132

11    - 139 114 133 104 90  137 103 78  33  79

21    - 94  120 67

TREES INCLUDED ARE -  OC30A OC30B OC30C

OC81
OC33M
24

1     - 79  162 116 119 119 158 95  159 152 156

11    - 66  118 117 93  101 77  90  115 80  105

21    - 53  75  73  78

TREES INCLUDED ARE -  OC33A OC33B OC33C
```

```
OC81
OC44M
29

1     - 59   82   256  129  193  186  178  151  150  119

11    - 127  117  128  98   85   78   105  87   68   67

21    - 64   55   64   60   56   46   80   53   56

TREES INCLUDED ARE -  OC44A OC44B OC44C

OC81
OC62M
24

1     - 68   231  170  173  129  171  141  117  113  90

11    - 103  69   76   63   96   76   48   38   42   23

21    - 51   86   97   93

TREES INCLUDED ARE -  OC62A OC62B


OC81
OC64
18

1     - 36   50   114  56   65   53   54   68   32   53

11    - 58   89   103  77   56   73   83   85




OC81
OC65M
52

1     - 62   129  176  169  174  180  156  126  110  137

11    - 102  97   103  79   131  85   62   46   58   39

21    - 54   37   22   19   22   17   24   33   37   47

31    - 15   16   24   15   15   14   15   11   34   50

41    - 33   24   22   33   15   47   23   37   27   31

51    - 29   20

TREES INCLUDED ARE -  OC65A OC65B OC65C
```

```
OC81
OC74M
17

1     - 26   160  118  165  188  116  137  137  242  254

11    - 301  245  193  175  162  174  163

TREES INCLUDED ARE -   OC74A OC74B OC74C




OC84
OC84A
101

1     - 0    67   67   101  99   87   58   61   88   56

11    - 83   72   82   97   101  78   45   68   64   77

21    - 72   72   51   58   60   74   70   65   79   63

31    - 83   43   32   33   35   47   64   63   62   72

41    - 88   77   54   55   58   40   25   37   36   45

51    - 46   46   57   55   49   53   50   47   72   83

61    - 124  103  94   95   84   117  77   92   90   67

71    - 72   50   44   33   37   37   34   45   32   28

81    - 42   34   36   48   38   37   55   45   49   52

91    - 47   25   25   33   32   32   23   20   24   30

101   - 27

COMMENT -    H/S AT R71


OC81
OC88M
49

1     - 112  93   115  97   87   84   86   52   96   120

11    - 120  87   132  49   88   91   91   75   30   42

21    - 71   78   70   47   83   95   26   38   85   34

31    - 47   79   72   31   107  130  76   31   45   74

41    - 65   66   60   11   39   86   60   57   78

TREES INCLUDED ARE -   OC88B OC88C
```

```
OC84
OC93A
112

1      - 0    150  117  117  163  93   63   115  78   101

11     - 110  62   55   80   60   64   76   88   91   70

21     - 92   94   112  149  111  134  97   103  90   78

31     - 61   55   78   58   36   50   57   61   61   79

41     - 92   70   125  138  107  144  108  57   83   126

51     - 160  94   83   70   77   114  81   118  88   75

61     - 86   77   170  109  122  94   128  242  264  244

71     - 194  79   96   71   76   41   48   45   33   37

81     - 59   54   56   44   52   71   53   47   36   46

91     - 68   44   39   40   31   33   47   28   40   41

101    - 53   50   37   41   37   39   28   31   31   41

111    - 40   29

COMMENT -    H/S AT R85


OC
OC100M
16

1      - 0    72   141  112  118  148  94   73   47   68

11     - 164  233  208  150  136  130

TREES INCLUDED ARE -   OC100A OC100B
```

```
OC81
OC103M
87

1     - 0   84  43  91  79  50  50  60  41  45

11    - 33  28  50  58  52  52  37  44  56  55

21    - 61  92  95  77  51  40  47  66  49  23

31    - 27  13  33  37  65  44  48  31  27  31

41    - 23  37  45  32  71  101 106 121 113 99

51    - 102 100 129 88  95  108 151 153 166 176

61    - 170 161 144 153 112 95  107 49  40  42

71    - 63  52  60  53  58  54  67  72  93  94

81    - 91  62  84  56  56  72  110

TREES INCLUDED ARE - OC103A OC103B


OC
OC104M
24

1     - 275 251 275 182 93  216 130 139 132 170

11    - 139 168 143 148 119 140 116 91  87  95

21    - 84  110 151 203

TREES INCLUDED ARE -  OC104A OC104B OC104C


OC81
OC107M
22

1     - 0   51  191 254 240 160 171 146 200 218

11    - 153 120 87  97  132 186 194 180 168 144

21    - 105 108

TREES INCLUDED ARE -  OC107A OC107B


OC81
OC108M
25

1     - 262 278 151 66  283 234 208 257 258 167

11    - 198 144 158 139 126 91  84  77  87  118

21    - 111 89  113 170 146

TREES INCLUDED ARE -  OC108A OC108B
```

```
OC81
OC109M
22

1     - 40  37  84  41  82  63  48  70  140 152

11    - 156 178 174 162 102 159 173 194 149 181

21    - 162 174

TREES INCLUDED ARE -  OC109A OC109B OC109C

OC81
OC112M
24

1     - 144 66  231 120 137 214 136 122 139 130

11    - 178 174 113 124 102 131 119 95  65  76

21    - 74  68  57  79

TREES INCLUDED ARE -  OC112A OC112B OC112C

OC81
OC124M
23

1     - 52  137 178 146 121 156 127 165 90  124

11    - 170 53  80  70  80  83  66  78  117 97

21    - 127 70  83

TREES INCLUDED ARE -  OC124A OC124B OC124C

OC
OC125M
19

1     - 0   161 74  64  45  51  38  53  86  78

11    - 121 105 80  76  120 87  116 133 107

TREES INCLUDED ARE -  OC125A OC125B

OC81
OC129M
24

1     - 76  134 170 117 94  122 44  57  51  51

11    - 87  72  93  88  62  115 86  75  122 146

21    - 183 169 170 271

TREES INCLUDED ARE -  OC129A OC129C
```

```
OC
OC132M
31

1     - 0    151  136  121  105  122  81   97   67   95

11    - 110  99   129  111  108  111  121  94   121  95

21    - 105  64   73   58   60   75   64   162  204  202

31    - 146

TREES INCLUDED ARE -  OC313B OC132C

OC81
OC133M
19

1     - 55   140  201  188  172  211  168  223  194  204

11    - 163  203  136  166  140  185  162  86   82

TREES INCLUDED ARE -  OC133A OC133B OC133C

OC84
OC141
80

1     - 0    49   57   84   81   70   90   58   83   71

11    - 75   62   122  71   43   53   35   36   32   41

21    - 85   62   100  111  127  117  131  67   48   56

31    - 110  48   42   41   30   53   41   69   78   56

41    - 83   61   74   68   58   53   97   87   113  104

51    - 72   55   40   55   39   57   34   49   44   58

61    - 44   29   40   35   44   52   46   51   57   62

71    - 64   32   23   12   27   36   47   45   39   39


COMMENT -    H/S AT R60
```

```
OC81
OC166M
16

1     - 163 234 179 166 145 162 118 105 139 167

11    - 167 194 192 182 164 162

TREES INCLUDED ARE -  OC166A OC166B OC166C




OC81
OC172M
21

1     - 119 53  130 118 155 91  81  69  73  88

11    - 90  27  28  42  95  188 257 255 237 189

21    - 223

TREES INCLUDED ARE -  OC172A OC172B OC172C

OC81
OC179M
22

1     - 0   157 222 257 241 274 177 175 260 150

11    - 154 188 239 188 163 169 205 212 205 165

21    - 164 180

TREES INCLUDED ARE -  OC119A OC119B OC119C

OC81
OC181M
24

1     - 42  54  19  22  27  107 147 153 117 130

11    - 83  83  63  89  74  60  44  72  63  115

21    - 111 128 116 101

TREES INCLUDED ARE -  OC181A OC181C
```

```
OC81
OC207M
20

1     - 69  75  80  86  72  58  96  94  94  77

11    - 107 135 144 178 174 165 179 187 219 168



TREES INCLUDED ARE -  OC207A OC207B

OC
OC214M
20

1     - 0   165 117 106 109 101 77  125 98  100

11    - 69  45  49  58  41  31  22  58  37  61



TREES INCLUDED ARE -  OC214A OC214B

OC
OC301M
22

1     - 56  86  127 63  54  33  40  61  87  111

11    - 108 232 137 176 143 75  116 106 74  54

21    - 102 137

TREES INCLUDED ARE -  OC301A OC301B OC301C

OC81
OC304M
18

1     - 66  66  25  60  27  15  48  37  46  33

11    - 63  38  42  58  67  65  83  100

TREES INCLUDED ARE -  OC304A OC304B

OC81
OC307M
20

1     - 116 36  61  29  53  45  73  66  41  73

11    - 69  103 105 108 108 136 125 125 137 155



TREES INCLUDED ARE -  OC307A OC307B
```

```
OC
OC308M
27

1     - 95   81   64   41   42   32   143  159  118  215

11    - 188  196  176  220  165  152  130  151  134  121

21    - 108  100  109  68   73   92   146

TREES INCLUDED ARE -  OC308A OC308B

OC
OC309M
26

1     - 60   226  270  201  174  166  118  173  100  77

11    - 84   57   98   88   91   100  118  45   110  88

21    - 123  146  108  92   121  166

TREES INCLUDED ARE -  OC309A OC309B

OC
OC310M
20

1     - 108  43   116  121  100  143  251  237  213  198

11    - 215  223  257  251  233  221  198  172  167  88



TREES INCLUDED ARE -  OC310B OC310C

OC
OC313M
30

1     - 29   57   72   45   87   50   138  76   144  114

11    - 89   166  127  158  171  159  139  160  134  160

21    - 124  93   95   51   63   74   136  187  167  106



TREES INCLUDED ARE -  OC313A OC313B OC313C
```

```
OC81
OC318M
24

1      - 112 146 141 98   99   103 48   28   20   26

11     - 34   10   9    16   28   20   16   33   27   30

21     - 46   58   30   51

TREES INCLUDED ARE -  OC318A OC318B OC318C


OC81
OC322M
38

1      - 63   72   45   43   37   36   39   23   170 134

11     - 118 64   54   57   37   20   17   12   21   17

21     - 30   16   13   12   15   12   13   19   14   15

31     - 31   20   12   11   13   15   43   0

TREES INCLUDED ARE -  OC322A OC322B OC322C


OC81
OC324M
29

1      - 93   75   54   47   51   44   44   32   29   35

11     - 64   50   57   49   29   27   31   43   40   45

21     - 60   33   39   42   23   26   33   54   60

TREES INCLUDED ARE -  OC324A OC324B


OC
OC326M
37

1      - 0    84   46   84   86   81   57   62   61   89

11     - 73   66   27   35   26   26   71   67   52   17

21     - 36   28   26   33   34   29   17   32   41   28

31     - 43   25   33   30   38   21   33

TREES INCLUDED ARE -  OC326A OC326B
```

```
OC81
OC328M
73

1     - 22   18   15   15   12   13   15   7    13   35

11    - 19   20   32   31   47   28   26   21   18   26

21    - 17   20   27   26   24   18   26   30   25   27

31    - 20   14   13   14   16   19   14   21   13   22

41    - 14   16   19   14   16   21   22   19   13   24

51    - 14   20   13   12   16   15   17   14   13   22

61      14   15   13   15   14   12   14   14   14   25

71    - 10   13   11

TREES INCLUDED ARE -  OC328A OC328B OC328C


OC81
OC329M
53

1     - 0    46   59   29   71   91   96   85   101  81

11      100  93   54   44   34   32   25   25   38   20

21    - 30   30   32   29   30   19   26   36   45   33

31    - 43   29   30   37   29   26   17   19   22   21

41    - 16   18   16   15   14   14   9    15   7    7

51    - 20   9    19

TREES INCLUDED ARE -  OC329A OC329B


OC81
OC332M
81

1     - 0    27   9    11   19   9    6    26   38   62

11    - 79   90   53   50   65   51   37   40   42   29

21    - 13   15   12   17   22   22   43   34   32   82

31    - 46   20   13   17   26   41   60   58   75   65

41    - 75   67   43   45   92   66   57   45   43   37

51    - 36   38   36   27   34   32   45   27   34   38

61    - 82   64   57   34   33   42   44   26   34   29

71    - 33   27   40   40   30   23   42   27   47   83

81    - 83

TREES INCLUDED ARE -  OC332A OC332B
```

```
OC81
OC335
22

1      - 41   12   27   64   101 64   63   69   76   40

11     - 73   68   46   69   38   32   69   56   39   46

21     - 66   47

COMMENT -

OC81
OC336M
77

1      - 56   45   43   43   23   25   25   24   29   40

11     - 27   26   34   21   21   16   15   12   15   26

21     - 23   15   11   19   16   30   17   23   24   38

31     - 15   24   24   23   21   21   17   19   14   30

41     - 17   25   32   15   25   17   25   20   28   46

51     - 32   20   19   22   24   18   17   25   24   32

61     - 20   16   14   25   20   26   22   22   15   41

71     - 42   24   16   14   22   19   21

TREES INCLUDED ARE -   OC336A OC336B

OC81
OC338M
67

1      - 0    28   38   11   38   46   21   28   38   23

11     - 18   23   10   17   13   25   38   18   21   18

21     - 36   40   17   14   18   17   16   15   37   22

31     - 18   21   15   16   9    12   21   17   16   21

41     - 12   17   10   16   8    13   11   13   12   30

51     - 36   35   42   38   38   31   25   17   26   24

61     - 35   35   26   30   19   25   19

TREES INCLUDED ARE -   OC338A OC338B
```

```
OC81
OC340M
52

1      - 0    57   85   94   62   24   19   38   35   22

11     - 44   28   24   26   27   27   32   42   54   55

21     - 90   45   40   28   37   31   34   22   29   35

31     - 50   33   22   32   24   21   15   32   26   32

41     - 40   25   20   22   13   8    10   13   13   16

51     - 25   20

TREES INCLUDED ARE -  OC340A OC340B

OC
OC341M
21

1      - 78   139  116  52   94   97   64   37   70   68

11     - 75   21   65   35   24   45   67   87   132  139

21     - 150

TREES INCLUDED ARE -  OC341B OC341C

OC
OC342M
20

1      - 140  164  125  140  154  155  137  141  114  58

11     - 93   82   74   102  94   108  121  123  117  98



TREES INCLUDED ARE -  OC342A OC342B OC342C

OC
OC343M
19

1      - 49   176  151  202  164  145  105  65   148  147

11     - 165  187  208  180  143  84   111  142  161

TREES INCLUDED ARE -  OC343A OC343B OC343C
```

```
OC
OC345M
25

1      - 0    33   159  141  118  211  118  110  124  191

11     - 161  141  146  159  133  118  75   65   47   74

21     - 85   92   86   78   120

TREES INCLUDED ARE -  OC345A OC345B OC345C


OC81
OC346M
24

1      - 121  121  277  192  242  260  145  166  212  229

11     - 188  175  144  151  156  160  132  92   72   83

21     - 111  119  123  98

TREES INCLUDED ARE -  OC346B OC346C

OC
OC349M
44

1      - 239  215  214  103  152  182  170  90   97   119

11     - 112  149  107  94   116  75   112  95   122  93

21     - 57   67   38   60   47   69   69   108  38   64

31     - 43   52   18   30   42   28   68   80   53   88

41     - 108  113  100  127

TREES INCLUDED ARE -  OC349A OC349B OC349C

OC81
OC353M
20

1      - 77   96   77   53   22   73   107  111  91   101

11     - 122  136  168  163  196  186  187  216  189  161


TREES INCLUDED ARE -  OC353A OC353B
```

```
OC81
OC356M
44

1      - 54   78   74   82   74   54   58   46   71   50

11     - 71   46   28   49   30   44   51   46   33   27

21     - 54   46   48   32   29   33   58   42   42   33

31     - 43   33   20   25   27   27   17   20   24   26

41     - 22   23   26   23

TREES INCLUDED ARE -  OC356A OC356B

OC
OC357M
17

1      - 0    220 255 181 106 130 145 169 114 115

11     - 122 132 100 109 110 67   75

TREES INCLUDED ARE -  OC357A OC357B OC357C

OC
OC358M
21

1      - 208 140 128 89   83   71   112 162 107 141

11     - 108 111 132 126 92   120 116 96   83   116

21     - 174

TREES INCLUDED ARE -  OC358A OC358B OC358C



OC81
OC369M
67

1      - 0    67   113 77   64   58   27   40   11   37

11     - 53   52   62   63   75   59   98   105 104 105

21     - 104 86   81   93   86   87   80   69   84   76

31     - 72   46   51   60   81   49   52   69   51   53

41     - 89   72   66   64   51   47   52   59   78   49

51     - 61   47   47   38   44   45   44   51   115 86

61     - 80   72   76   79   60   109 79

TREES INCLUDED ARE - OC369A OC369B
```

```
OC81
OC370M
47

1      - 0    109 73   105 121 102 109 94   101 115

11     - 121  104 132  158 157 122 109 125  114 98

21     - 136  80  67   58  81  74  84  67   46  35

31     - 60   61  46   47  49  53  51  35   25  32

41     - 44   34  36   21  42  48  38

TREES INCLUDED ARE OC370A OC370B


OC84
OC372
28

1      - 118  87  85   105 95  139 83  111  123 113

11     - 130  94  92   75  137 120 121 121  72  122

21     - 156  151 134  131 105 117 122 99

H/S AT R16

OC
OC376M
50

1      - 55   9   185  106 70  213 164 137  126 66

11     - 109  124 78   88  100 78  82  97   95  86

21     - 111  72  137  103 96  82  50  49   56  76

31     - 67   64  156  152 45  82  84  32   37  87

41     - 69   103 130  62  41  91  38  72   63  74


TREES INCLUDED ARE -  OC376A OC376B OC376C
```

```
OC
OC379M
44

1      - 57   71   116  88   114  147  98   79   161  152

11     - 156  138  55   74   51   43   56   55   64   88

21     - 67   46   42   47   51   48   53   62   37   48

31     - 49   36   69   64   69   57   79   59   31   54

41     - 47   80   28   82

TREES INCLUDED ARE -  OC379A OC379B OC379C


OC81
OC380M
98

1      - 0    115  107  135  189  152  85   86   55   48

11     - 59   75   46   54   50   51   44   40   47   72

21     - 94   74   82   64   93   73   66   55   76   95

31     - 89   57   54   64   68   63   56   52   51   45

41     - 62   94   56   61   63   61   42   44   58   49

51     - 56   56   39   27   73   52   55   52   36   58

61     - 60   52   37   63   47   31   42   45   46   54

71     - 41   52   37   48   37   57   45   64   66   58

81     - 55   54   49   61   45   34   44   47   38   30

91     - 38   31   24   33   33   41   49   44

TREES INCLUDED ARE - OC380A OC380B

OC
OC381M
27

1      - 115  59   40   37   149  135  112  190  154  192

11     - 198  147  97   67   71   106  66   86   85   70

21     - 60   44   46   55   65   62   60

TREES INCLUDED ARE -  OC381A OC381B OC381C
```

OC81
OC383M

```
60

1      - 31   21   17   12   18   15   21   17   17   24

11     - 30   23   35   32   32   29   32   36   28   18

21     - 21   22   26   22   32   28   27   23   28   31

31     - 41   41   34   25   31   28   17   31   18   19

41     - 25   21   16   18   10   13   10   17   13   13

51     - 18   16   13   9    10   13   9    13   12   14



TREES INCLUDED ARE -  OC383A OC383B
```

OC81
OC384M

```
26

1      - 71   187  176  138  179  123  104  50   43   117

11     - 84   58   72   90   84   85   73   117  90   121

21     - 142  98   92   87   123  167

COMMENT -
```

OC
OC385M

```
23

1      - 163  66   126  59   162  118  130  71   55   136

11     - 113  134  132  127  104  119  76   116  122  117

21     - 99   96   112

TREES INCLUDED ARE -  OC385A OC385B
```

OC
OC386M

```
21

1      - 148  303  223  274  273  196  225  237  232  203

11     - 184  163  186  181  188  144  114  106  115  97

21     - 74

TREES INCLUDED ARE -  OC386A OC386B OC386C
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```
OC
OC387M
21

1      - 148 134 154 128 125 80   69   138 80   73

11     - 83   142 140 132 99   117 110 126 105 85

21     - 93

TREES INCLUDED ARE -   OC387A OC387B OC387C


OC
OC391M
29

1      - 0    187 164 129 105 48   67   56   96   70

11     - 76   143 126 149 123 126 139 144 161 158

21     - 133 113 110 88   74   102 158 181 109

TREES INCLUDED ARE -   OC391A OC391B

OC81
OC392M
25

1      - 55   144 101 92   120 87   138 95   128 137

11     - 124 110 75   84   109 149 134 167 155 162

21     - 188 172 119 191 172

TREES INCLUDED ARE -   OC392A OC392B

OC81
OC399M
25

1      - 0    77   58   53   52   35   39   36   50   50

11     - 81   75   39   18   19   45   87   89   107 133

21     - 116 116 142 92   117

TREES INCLUDED ARE -   OC399A OC399B
```

```
OC
OC400M
26

1     - 0   63  105 128 116 121 96  76  36  66

11    - 115 158 163 149 117 96  77  86  60  59

21    - 79  50  107 75  104 0

TREES INCLUDED ARE -  OC400A OC400B OC400C

OC
OC401M
17

1     - 0   281 243 123 79  115 81  26  90  80

11    - 90  77  83  109 113 95  21

TREES INCLUDED ARE -  OC401A OC401C

OC81
OC402M
40

1     - 0   101 79  59  60  52  62  52  52  47

11    - 44  32  25  26  31  51  31  29  28  34

21    - 44  30  31  28  30  31  36  26  20  19

31    - 35  18  24  31  35  53  49  40  29  42


TREES INCLUDED ARE -  OC402A OC402B


OC
OC403M
21

1     - -1  35  26  27  40  63  59  107 137 113

11    - 156 117 112 111 79  154 127 140 167 141

21    - 135

TREES INCLUDED ARE - OC403A OC403B OC403C
```

```
OC
OC408M
20

1     - 97   122 65   100 127 80   56   118 60   286

11    - 216 118 162 98   103 84   133 172 193 157


TREES INCLUDED ARE -  OC408A OC408B OC408C

OC81
OC409M
30

1     - 0    72   40   56   71   50   53   40   59   71

11    - 95   121 87   175 221 136 141 78   93   78

21    - 71   49   46   40   47   25   8    20   10   28


TREES INCLUDED ARE -  OC409A OC409B OC409C

OC81
OC411M
20

1     - 0    95   103 66   81   65   101 141 132 110

11    - 151 128 137 125 96   112 92   122 109 93


TREES INCLUDED ARE -  OC411A OC411B

OC81
OC414M
39

1     - 0    53   20   15   14   15   45   39   35   42

11    - 45   16   19   21   18   22   65   133 108 89

21    - 105 77   75   79   65   71   70   95   92   83

31    - 79   43   38   35   31   23   26   28   23

TREES INCLUDED ARE -  OC414A OC414B
```

```
OC
OC419M
16

1     - 0   191 129 130 137 76  187 246 211 135

11    - 207 214 191 170 213 207

TREES INCLUDED ARE -  OC419A OC419C


OC
OC420M
24

1     - 0   142 116 52  89  154 141 165 193 239

11    - 205 146 139 187 158 155 120 116 98  107

21    - 136 162 165 173

TREES INCLUDED ARE -  OC420A OC420B OC420C


OC
OC421M
28

1     - 0   74  178 108 124 96  123 165 136 180

11    - 165 167 109 153 143 129 136 118 128 131

21    - 101 99  46  87  100 109 82  84

TREES INCLUDED ARE -  OC421A OC421B OC421C


OC81
OC423
28

1     - 0   85  61  58  59  55  51  88  70  53

11    - 55  51  65  52  51  65  63  40  34  56

21    - 53  34  21  38  52  59  42  41

COMMENT -


2
OC424M
19

1     - 63  159 127 83  44  47  29  167 110 107

11    - 159 131 187 150 182 208 226 177 198

TREES INCLUDED ARE -  OC424A OC424B OC424C
```

```
OC81
OC428M
23

1     - 109 150 104 86  88  82  77  94  38  67

11    - 50  70  38  36  54  16  27  25  23  17

21    - 40  31  62

TREES INCLUDED ARE -  OC428A OC428B

OC81
OC433M
17

1     - 77  107 43  44  29  19  31  31  59  32

11    - 57  26  30  18  19  18  23

TREES INCLUDED ARE -  OC433A OC433B

OC81
OC446M
71

1     - 57  69  103 120 76  73  86  101 90  95

11    - 54  72  84  85  64  52  58  51  48  51

21    - 76  73  67  74  67  86  67  81  54  31

31    - 51  56  56  106 47  43  34  41  38  45

41    - 38  19  19  19  11  23  8   38  19  39

51    - 64  61  44  45  25  17  24  19  30  52

61    - 21  22  27  30  9   18  22  39  40  22

71    - 11

TREES INCLUDED ARE -  OC446A OC446B OC446C OC446D

OC
OC447M
20

1     - 0   38  148 128 169 154 102 130 139 135

11    - 120 96  117 77  123 86  68  62  46  65


TREES INCLUDED ARE -  OC447A OC447B OC447C
```

```
OC81
OC452M
67

1     - 53   18   59   47   24   22   18   26   13   18

11    - 21   11   9    13   13   10   11   12   12   8

21    - 8    12   10   9    35   65   79   32   76   66

31    - 71   45   33   37   38   39   53   51   32   27

41    - 39   54   49   64   63   52   64   53   49   50

51    - 70   63   35   49   55   71   51   64   49   58

61    - 68   52   32   30   33   46   101

TREES INCLUDED ARE -  OC452A OC452B

OC
OC459M
18

1     - 119  136  104  126  112  108  144  111  128  77

11    - 68   100  89   109  94   72   57   57

TREES INCLUDED ARE -  OC459A OC459B OC459C

OC
OC460M
17

1     - 110  101  179  87   57   82   93   84   94   90

11    - 130  97   144  92   69   57   72

TREES INCLUDED ARE -  OC460B OC460C OC460D

OC81
OC461M
26

1     - 256  172  121  106  99   112  63   35   49   65

11    - 46   46   33   49   49   46   37   30   22   79

21    - 32   47   37   33   20   16

TREES INCLUDED ARE -  OC461A OC461B OC461C
```

```
OC
OC462M
29

1    - 100 63  104 161 123 118 73  189 181 190

11   - 162 159 161 161 185 163 174 114 116 99

21   - 109 114 89  70  50  37  51  75  88

TREES INCLUDED ARE -  OC462A OC462B

OC
OC466M
19

1    - 71  126 235 107 89  133 112 86  117 146

11   - 188 163 145 140 160 170 127 159 130

TREES INCLUDED ARE -  OC466A OC466B



OC81
OC467
18

1    - 0   160 202 261 218 156 99  301 333 333

11   - 298 205 254 242 227 109 218 203




OC
OC471M
26

1    - 0   201 203 250 169 142 88  109 56  55

11   - 42  102 173 93  108 57  76  71  111 79

21   - 64  54  67  62  42  57

TREES INCLUDED ARE -  OC471A OC471B OC471C
```

```
OC81
OC473M
138

1     - 0    39   28   32   27   37   27   24   9    49

11    - 42   29   37   37   51   52   48   34   60   98

21    - 107  113  173  143  98   65   72   56   52   63

31    - 53   30   26   22   21   22   22   24   36   14

41    - 19   18   16   25   24   56   81   79   77   66

51    - 75   107  96   111  79   74   93   101  89   54

61    - 38   49   54   61   49   51   56   34   50   42

71    - 59   62   52   43   39   53   38   57   49   32

81    - 48   19   13   16   22   29   23   30   41   21

91    - 40   17   26   22   15   25   26   31   29   42

101   - 44   37   29   21   19   27   25   33   28   24

111   - 36   17   34   40   49   54   52   58   66   43

121   - 65   46   52   50   53   65   47   68   60   43

131   - 62   65   42   30   40   43   38   24

TREES INCLUDED ARE - OC473A OC473B


OC
OC481M
32

1     - 0    77   98   159  151  157  113  105  105  146

11    - 89   115  101  84   68   72   67   94   49   83

21    - 71   77   96   89   80   84   87   61   27   43

31    - 50   41

TREES INCLUDED ARE -  OC481A OC481B OC481C


OC
OC482M
17

1     - 0    188  177  238  274  132  140  214  110  96

11    - 106  78   90   71   61   109  93

TREES INCLUDED ARE -  OC482A OC482B OC482C
```

```
OC81
OC484M
21

1      - 186 213 163 149 130 134 120 119 88  80

11     - 59  63  45  64  64  51  73  74  59  59

21     - 68

TREES INCLUDED ARE -  OC484A OC484B OC484C


OC
OC487M
22

1      - 78  133 116 98  114 112 125 157 141 154

11     - 133 120 125 120 148 109 159 143 134 155

21     - 178 141

TREES INCLUDED ARE -  OC487A OC487B


OC81
OC488M
29

1      - 64  103 67  57  68  75  74  61  92  72

11     - 117 105 107 84  84  111 82  79  55  53

21     - 78  83  72  73  19  11  57  102 82

TREES INCLUDED ARE -  OC488A OC488B


OC
OC490M
25

1      - 147 223 158 143 109 111 107 89  142 191

11     - 94  74  97  104 94  92  80  98  76  120

21     - 109 88  74  104 137

TREES INCLUDED ARE -  OC490A OC490B  OC490C
```

```
OC81
OC497
86

1     - 0   97  80  45  56  52  49  37  45  64

11    - 99  81  89  100 54  87  76  106 70  73

21    - 82  52  48  59  51  64  63  34  37  25

31    - 38  29  47  24  38  25  22  24  13  35

41    - 50  22  38  61  34  25  34  24  20  19

51    - 45  30  35  32  48  82  59  54  58  47

61    - 59  49  33  31  42  25  29  36  33  29

71    - 35  33  28  38  43  48  52  63  56  52

81    - 55  31  23  47  57  59

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OC81
OC499M
27

1     - 190 154 173 157 190 176 192 109 137 166

11    - 139 141 127 153 130 124 102 117 91  112

21    - 102 54  70  66  65  57  93

TREES INCLUDED ARE -  OC499A OC499B OC499C

OC81
OC504M
50

1     - 68  166 133 90  54  62  81  57  76  32

11    - 89  66  87  100 45  59  56  88  92  83

21    - 83  110 105 107 116 68  61  62  55  75

31    - 129 171 146 95  259 249 157 150 151 143

41    - 246 368 280 197 229 263 236 248 212 243


TREES INCLUDED ARE -  OC504A OC504B
```

```
OC
OC505M
59

1     - 93   64   32   68   71   87   70   69   69   61

11    - 79   95   47   41   56   53   50   49   40   52

21    - 31   18   26   29   16   13   15   8    15   43

31    - 56   55   36   39   33   43   57   54   71   45

41    - 26   50   62   61   40   40   31   28   39   58

51    - 29   26   31   12   43   44   34   51   69

TREES INCLUDED ARE -  OC505A OC505B


OC81
OC506M
28

1     - 69   100  114  45   96   132  127  158  169  320

11    - 254  200  185  201  222  213  207  110  114  92

21    - 119  62   77   151  180  107  138  123

TREES INCLUDED ARE -  OC506A OC506B


OC
OC511M
15

1     - 195  159  120  155  118  102  114  88   86   76

11    - 108  88   70   48   49

TREES INCLUDED ARE -  OC511A OC511B


OC81
OC512M
62

1     - 20   42   29   25   22   25   31   31   21   34

11    - 49   31   27   36   39   38   26   26   35   34

21    - 21   18   28   13   18   15   17   19   14   16

31    - 25   10   10   11   16   9    9    12   11   12

41    - 26   12   13   12   11   18   16   16   15   14

51    - 28   14   20   16   14   14   11   12   10   8

61    - 17   9

TREES INCLUDED ARE -  OC512A OC512B
```

```
OC81
OC513M
27

1     - 25   96   94   72   69   93   41   46   48   44

11    - 75   28   57   15   41   22   16   17   15   27

21    - 32   18   13   19   22   27   42

TREES INCLUDED ARE -  OC513A OC513B

OC81
OC517M
19

1     - 57   59   77   30   40   38   47   57   58   62

11    - 88   200  158  93   96   68   107  72   62

TREES INCLUDED ARE -  OC517A OC517B

OC
OC520M
18

1     - 29   149  86   125  128  97   118  107  80   99

11    - 95   80   102  83   95   82   74   68

TREES INCLUDED ARE -  OC520A OC520B OC520C

OC
OC522M
16

1     - 32   82   71   149  123  115  122  84   75   87

11    - 67   53   51   37   47   65

TREES INCLUDED ARE -  OC522A OC522B OC522C

OC81
OC523M
21

1     - 144  86   41   61   65   66   34   31   46   44

11    - 82   57   99   76   76   60   96   57   86   102

21    - 91

TREES INCLUDED ARE -  OC523A OC523B
```

```
OC
OC525M
19

1     - 97  134 91  88  86  91  185 109 155 115

11    - 91  107 97  97  87  80  68  87  63

TREES INCLUDED ARE -  OC525A OC525B OC525C


OC
OC527M
33

1     - 141 37  45  27  36  61  40  96  70  58

11    - 69  84  68  37  64  42  106 98  84  51

21    - 39  37  33  40  59  51  46  35  29  18

31    - 13  14  15

TREES INCLUDED ARE -  OC527A OC527B  OC527C

OC
OC533M
22

1     - 0   101 65  71  97  111 94  97  111 58

11    - 144 138 137 142 108 83  74  62  50  30

21    - 33  24

TREES INCLUDED ARE -  OC533A OC533B OC533C

OC
OC534M
32

1     - 0   56  197 139 231 212 198 157 129 115

11    - 185 146 96  107 64  99  64  52  89  84

21    - 87  98  114 84  67  48  54  35  34  20

31    - 29  25

TREES INCLUDED ARE -  OC534A OC534B OC534C
```

```
OC81
OC542M
54

1     - 34   58   46   25   23   20   17   13   12   19

11    - 45   20   18   13   19   25   20   15   18   23

21    - 44   31   40   44   37   22   29   25   34   36

31    - 44   25   27   19   22   20   21   20   24   29

41    - 38   22   21   31   27   26   17   22   24   14

51    - 32   20   19   42

TREES INCLUDED ARE -  OC542A OC542B


OC81
OC543M
19

1     - 30   72   113 80   77   108 66   86   85   121

11    - 101 45   21   22   29   36   47   55   50

TREES INCLUDED ARE -  OC543A OC543B


OC
OC548M
19

1     - 0    84   125 88   56   66   90   60   142 116

11    - 144 146 106 84   72   68   62   58   43

TREES INCLUDED ARE -  OC548B OC548C


OC
OC550M
16

1     - 0    32   86   65   157 101 125 129 99   114

11    - 106 85   80   76   63   56

TREES INCLUDED ARE -  OC550A OC550B OC550C


OC
OC555M
23

1     - 0    48   61   150 126 156 55   45   107 189

11    - 106 58   86   59   45   46   28   24   9    5

21    - 18   26   36
```

```
OC81
OC561M
31

1     - 0    152 63   40   62   76   95   100 109 77

11    - 141  120 81   79   52   49   54   54   65   33

21    - 64   14   32   33   13   22   27   51   21   32

31    - 12

TREES INCLUDED ARE -  OC561A OC561B OC561C

OC81
OC564M
31

1     - 24   11   54   42   25   25   26   19   145 124

11    - 79   48   53   53   43   22   24   16   30   28

21    - 37   28   19   23   15   14   14   11   8    13

31    - 24

TREES INCLUDED ARE -  OC564A OC564B

OC81
OC571M
19

1     - 83   139 92   91   85   59   68   47   33   28

11    - 43   23   29   28   19   31   31   26   54

TREES INCLUDED ARE -  OC571A OC571B

OC81
OC582M
27

1     - 191 71   76   54   73   63   67   67   33   48

11    - 28   33   29   14   26   20   23   13   25   21

21    - 42   25   22   75   102 90   0

TREES INCLUDED ARE -  OC582A OC582B OC582C
```

```
OC
OC584M
17

1    - 35  76  103 131 88  82  57  114 90  63

11   - 120 72  95  82  74  81  111

TREES INCLUDED ARE -  OC584A OC584B

OC81
OC585M
22

1    - 99  99  71  92  82  144 60  114 87  74

11   - 128 87  80  82  82  70  94  78  77  67

21   - 63  67

TREES INCLUDED ARE -  OC585A OC585B OC585C

OC81
OC589M
24

1    - 63  86  62  91  65  57  40  30  138 117

11   - 144 124 92  106 102 66  54  45  28  41

21   - 44  50  65  63

COMMENT - 6 SERIES INCLUDED

OC
OC600M
18

1    - 96  196 288 237 277 136 142 188 113 99

11   - 85  93  90  79  71  123 89  138

TREES INCLUDED ARE -  OC600A OC600B
```

```
OC
OC603M
53

1     - 0   131 92  64  48  62  42  52  27  104

11    - 74  126 68  15  11  10  9   6   16  8

21    - 8   10  11  7   6   6   6   6   6   6

31    - 15  17  11  21  9   21  15  36  33  78

41    - 86  77  43  59  38  60  51  54  18  19

51    - 42  57  54

TREES INCLUDED ARE -  OC603B OC603C

OC
OC604M
24

1     - 0   117 93  121 151 145 121 91  101 73

11    - 96  135 113 121 121 74  80  102 135 121

21    - 108 79  80  80

TREES INCLUDED ARE -  OC604B OC604C


OC
OC606M
55

1     - 0   82  36  60  140 95  150 118 59  77

11    - 37  60  81  76  64  50  43  32  36  39

21    - 40  22  40  28  34  45  44  45  42  36

31    - 41  44  44  43  15  27  40  21  14  11

41    - 16  26  39  36  35  28  23  23  45  42

51    - 19  28  41  35  20

TREES INCLUDED ARE -  OC606A OC606B OC606C
```

```
OC81
OC608M
62

1     - 131 219 146 115 73  67  64  57  63  71

11    - 63  46  46  23  19  40  24  27  22  24

21    - 12  5   16  5   12  13  66  83  83  90

31    - 83  53  49  22  36  53  51  62  40  48

41    - 36  22  47  20  27  16  15  11  17  14

51    - 25  31  26  17  16  16  12  10  15  18

61    - 27  10

TREES INCLUDED ARE -  OC608A OC608B
```

```
OC81
OC613M
25

1     - 69  129 182 157 140 125 155 97  74  132

11    - 65  85  116 120 91  97  76  117 98  121

21    - 73  54  44  64  57

TREES INCLUDED ARE -  OC613A OC613C
```

```
OC81
OC616M
60

1     - 43  77  66  109 91  77  92  38  85  123

11    - 107 71  51  41  30  36  45  51  30  36

21    - 59  61  53  52  48  43  41  52  41  45

31    - 53  22  35  44  24  15  12  14  17  21

41    - 42  25  24  19  23  44  39  14  32  32

51    - 43  24  31  33  43  41  38  69  48  45


TREES INCLUDED ARE -  OC616A OC616B OC616C
```

```
OC
OC618M
56

1     - 83   108 61   148 113 148 74   47   49   40

11    - 94   122 94   87   70   37   65   56   75   62

21    - 30   59   80   123 82   53   53   28   38   53

31    - 21   29   50   25   31   46   20   21   29   35

41    - 22   25   32   31   26   34   38   51   34   18

51    - 33   29   35   33   45   38

TREES INCLUDED ARE -  OC618A OC618B OC618C


OC81
OC620M
38

1     - 53   93   49   49   28   26   6    7    9    4

11    - 11   8    11   14   140 80   74   47   32   29

21    - 29   23   17   19   20   15   19   19   49   58

31    - 70   54   37   33   40   31   42   38

TREES INCLUDED ARE -  OC620A OC620B


OC81
OC621
21

1     - 85   53   69   44   85   66   101 99   86   120

11    - 85   149 133 140 147 149 161 137 164 183

21    - 167

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OC81
OC629M
33

1     - 37   96   59   60   10   8    9    21   65   96

11    - 85   80   83   72   73   69   62   73   79   59

21    - 59   73   66   59   46   40   44   12   15   33

31    - 73   42   85

TREES INCLUDED ARE -  OC629A OC629B OC629C
```

```
OC
OC637M
22

1     - 0    75   98   110  57   101  110  62   64   65

11    - 83   63   45   32   34   101  82   83   95   124

21    - 166  210

TREES INCLUDED ARE -  OC637A OC637B OC637C

OC81
X1M
33

1     - 0    235  125  162  148  150  117  162  130  87

11    - 67   76   108  99   77   102  155  121  100  114

21    - 109  82   95   64   106  115  127  80   94   48

31    - 49   55   74

TREES INCLUDED ARE -  X1A X1B X1C

OC81
X2M
35

1     - 0    85   102  104  63   101  75   79   122  141

11    - 127  99   91   93   131  94   124  125  111  87

21    - 62   95   46   75   91   66   103  107  138  126

31    - 53   32   42   35   65

TREES INCLUDED ARE -  X2A X2B X2C

OC81
X3M
33

1     - 0    199  52   151  146  168  195  173  178  116

11    - 83   74   81   80   67   60   72   54   58   48

21    - 36   31   42   32   78   73   76   67   60   69

31    - 94   94   110

TREES INCLUDED ARE -  X3A X3B X3C
```

```
OC81
X4M
60

1     - 0   183 188 156 151 136 206 140 213 165

11    - 168 165 142 162 142 132 128 119 81  83

21    - 107 105 56  49  48  51  47  45  56  69

31    - 85  46  38  15  20  20  16  11  8   23

41    - 27  34  77  76  40  55  48  47  27  28

51    - 62  60  82  40  42  52  38  66  59  51



TREES INCLUDED ARE X4A X4B X4C X4D


OC81
X5M
41

1     - 0   78  184 80  79  134 150 147 155 187

11    - 122 88  55  110 81  131 60  46  26  16

21    - 15  17  24  35  73  36  65  92  69  50

31    - 63  65  9   77  86  99  70  34  44  71

41    - 74

TREES INCLUDED ARE -  X5A X5B X5C

OC81
X6M
33

1     - 0   37  76  104 136 165 267 180 114 98

11    - 93  164 142 102 145 153 117 132 78  87

21    - 87  113 118 96  150 150 108 131 20  134

31    - 170 167 230

TREES INCLUDED ARE -  X6A X6B X6C
```

```
OC81
X7M
51

1     - 0    34   67   86   106  113  112  110  92   99

11    - 106  110  107  104  80   61   59   65   77   74

21    - 89   112  118  106  93   87   115  137  159  148

31    - 176  188  162  154  148  149  159  176  152  162

41    - 114  148  173  88   43   60   75   112  153  179

51    - 183

TREES INCLUDED ARE -   X7A X7B X7C

OC81
X8M
53

1     - 0    89   55   102  92   74   150  177  165  133

11    - 135  118  106  115  111  110  100  75   68   90

21    - 150  152  129  127  166  163  165  156  112  136

31    - 152  201  143  145  154  104  187  144  161  113

41    - 175  154  92   35   120  116  55   15   12   19

51    - 66   86   94

TREES INCLUDED ARE -   X8A X8B X8C

OC81
X9M
47

1     - 0    256  123  68   28   23   73   134  103  181

11    - 104  60   82   86   111  111  134  126  123  117

21    - 149  113  126  104  81   82   61   64   47   78

31    - 102  98   85   87   86   66   54   45   21   41

41    - 72   62   46   34   39   42   64

TREES INCLUDED ARE -   X9A X9B X9C
```

```
OC81
X10M
36

1     - 0   82  97  157 176 156 140 146 179 157

11    - 156 117 92  47  49  68  85  71  69  90

21    - 72  81  82  58  42  55  42  107 93  136

31    - 72  98  42  56  43  39

TREES INCLUDED ARE -  X10A X10B X10C

OC81
X11M
45

1     - 0   76  30  95  100 113 103 74  34  88

11    - 80  92  89  124 91  79  51  97  76  101

21    - 98  60  56  46  59  55  69  81  114 65

31    - 55  49  60  55  51  42  53  89  77  54

41    - 24  56  55  61  75



OC81
X12M
26

1     - 0   162 183 164 173 164 219 223 234 186

11    - 221 223 181 122 126 212 237 162 167 169

21    - 181 209 183 134 94  113

TREES INCLUDED ARE -  X12A X12B


X12AM
44

1     - 0   81  161 112 95  94  43  26  31  57

11    - 81  129 107 86  97  123 121 130 61  64

21    - 65  68  71  81  92  92  91  68  42  62

31    - 103 100 80  48  107 115 158 103 44  15

41    - 28  25  24  47

TREES INCLUDED ARE -  X12AA X12AB
```

```
OC81
X13M
37

1     - 0    161  41   144  141  168  106  162  172  167

11    - 142  116  98   81   86   83   101  103  95   110

21    - 99   79   90   107  103  104  123  118  91   87

31    - 24   91   75   105  21   59   48

TREES INCLUDED ARE -   X13A  X13B   X13C


OC81
X15M
50

1     - 0    23   171  158  110  152  111  105  98   113

11    - 120  106  69   48   70   65   74   88   78   74

21    - 58   43   67   56   60   54   45   37   38   29

31    - 32   34   51   44   40   32   33   30   28   29

41    - 29   35   53   44   30   28   31   35   39   60


COMMENT - 7 SERIES INCLUDED

OC81
X16M
50

1     - 0    76   123  275  179  218  188  139  111  98

11    - 134  99   127  55   81   86   104  104  86   97

21    - 83   66   83   60   65   36   30   39   32   32

31    - 29   40   40   38   34   31   30   28   25   24

41    - 39   31   28   34   26   28   22   51   26   57


TREES INCLUDED ARE -   X16A  X16B  X16C  X16D
```

```
OC81
X17M
25

1     - 74   206 187 161 135 177 218 268 224 196

11    - 232 213 169 120 117 108 79   87   81   60

21    - 87   105 70   53   39

TREES INCLUDED ARE -   X17A X17B X17C

OC81
X18M
19

1     - 0    57   167 126 170 146 163 216 219 249

11    - 177 259 176 229 148 176 164 193 217

TREES INCLUDED ARE -   X18A X18B X18C

OC81
X19M
19

1     - 0    137 190 172 149 138 124 108 85   116

11    - 164 142 152 184 192 185 253 225 199

TREES INCLUDED ARE -   X19A X19B X19C

OC81
X20M
21

1     - 0    143 264 285 287 223 219 179 180 183

11    - 189 178 214 149 177 129 149 136 142 115

21    - 128

TREES INCLUDED ARE -   X20A X20B X20C

OC81
X21M
30

1     - 0    54   128 102 166 156 157 139 109 157

11    - 143 122 142 72   122 109 93   42   66   81

21    - 95   62   110 74   96   95   101 90   125 77


TREES INCLUDED ARE -   X21A X21B X21C X21D
```

```
OC81
X22M
25

1     - 0   63  81  137 123 142 164 160 168 156

11    - 221 180 181 185 186 233 258 202 233 141

21    - 167 203 158 87  114

TREES INCLUDED ARE -  X22A X22B X22C

OC81
X23M
27

1     - -2  185 203 205 233 175 152 170 212 201

11    - 192 96  175 163 123 93  99  95  110 69

21    - 79  40  75  87  86  70  60

TREES INCLUDED ARE -  X23A X23B X23C

OC81
X24M
32

1     - 0   43  109 73  98  153 115 121 27  48

11    - 60  87  65  132 130 144 112 128 76  115

21    - 102 99  114 152 119 138 58  109 120 106

31    - 90  98

TREES INCLUDED ARE -  X24A X24B X24C

OC81
X25M
35

1     - 0   114 47  138 133 148 130 141 106 144

11    - 106 98  106 84  136 158 156 132 106 128

21    - 128 150 147 114 102 133 116 150 83  132

31    - 137 133 104 169 174

TREES INCLUDED ARE -  X25B X25C
```

```
OC81
X26M
21

1      - 0   114 98  157 103 202 203 116 184 162

11     - 164 120 175 137 162 105 151 107 98  111

21     - 126

TREES INCLUDED ARE -   X26A X26B X26C

OC81
X27M
21

1      - 0   235 88  275 216 204 261 235 201 220

11     - 189 194 245 215 210 187 216 188 216 174

21     - 103

TREES INCLUDED ARE -   X27A X27B X27C

OC81
X28M
27

1      - 0   45  173 167 175 130 103 123 155 168

11     - 158 146 146 162 129 115 151 148 91  62

21     - 83  87  96  114 116 127 96

TREES INCLUDED ARE -   X28A X28B X28C

OC81
X29M
32

1      - 0   35  111 114 108 134 113 129 107 126

11     - 104 115 128 140 147 168 125 151 125 126

21     - 125 90  98  118 69  75  49  91  97  82

31     - 68  94

TREES INCLUDED ARE -   X29A X29B X29C
```

```
OC81
X30M
23

1    - 0   133 125 151 120 126 182 126 177 151

11   - 159 118 159 167 166 113 156 121 144 161

21   - 148 146 98

TREES INCLUDED ARE -  X30B X30B X30C

OC81
X31M
29

1    - 0   46  46  80  156 113 161 128 140 165

11   - 139 178 122 197 148 145 131 128 154 146

21   - 84  125 143 149 177 211 187 96  262

TREES INCLUDED ARE -  X31A X31B X31C

OC81
X32M
28

1    - 0   103 196 171 140 111 138 95  119 145

11   - 158 172 107 133 114 81  54  77  115 119

21   - 36  110 93  116 97  70  54  76

TREES INCLUDED ARE -  X32A X32B X32C

OC81
X33M
49

1    - 0   34  31  115 110 117 181 190 156 211

11   - 191 235 185 123 149 105 142 142 127 144

21   - 131 92  121 96  135 71  56  57  59  66

31   - 64  41  81  99  58  47  66  40  14  49

41   - 43  11  76  61  43  29  35  43  57

TREES INCLUDED ARE -  X33A X33B X33C
```

```
OC81
X34M
31

1      - 0    96   166  136  96   88   141  73   110  93

11     - 90   114  101  107  122  59   121  96   71   111

21     - 82   68   109  82   85   36   83   71   80   61

31     - 54

TREES INCLUDED ARE -   X34A X34B  X34C

OC81
X35M
26

1      - -1   59   31   114  102  135  121  190  168  168

11     - 83   137  133  126  107  89   88   119  66   109

21     - 59   94   70   87   96   116

TREES INCLUDED ARE -   X35A X35B X35C

OC81
X36M
25

1      - 0    193  173  166  159  120  155  151  187  105

11     - 169  123  122  117  98   107  122  95   95   48

21     - 83   80   75   56   71

TREES INCLUDED ARE -   X36A X36B X36C

OC81
X37M
29

1      - 0    83   115  82   152  150  108  89   126  159

11     - 194  186  170  220  171  212  184  131  230  220

21     - 154  134  119  146  130  124  79   99   70

TREES INCLUDED ARE -   X37A X37B X37C
```

```
OC81
X38M
22

1      - 0    91   299 287 250 290 166 196 249 242

11     - 282 242 212 265 366 292 389 226 280 235

21     - 283 217

TREES INCLUDED ARE -   X38A X38B X38C


X39M
25

1      - 0    235 169 254 237 274 265 285 294 251

11     - 197 183 137 135 147 112 73   96   65   51

21     - 104 159 172 179 61

TREES INCLUDED ARE -   X39A X39B



OC81
X40
113

1      - 0    34   35   22   28   21   31   21   19   30

11     - 43   41   32   32   52   57   44   36   47   58

21     - 72   70   79   63   74   78   66   56   110 99

31     - 114 97   119 93   147 122 131 173 120 128

41     - 124 107 47   116 77   114 117 130 125 115

51     - 149 111 100 56   56   65   38   45   52   40

61     - 80   36   48   57   32   58   52   60   48   44

71     - 63   34   42   49   28   32   37   46   30   20

81     - 24   15   23   28   20   36   37   49   89   59

91     - 49   68   101 66   79   78   66   95   78   59

101    - 56   56   62   105 86   88   113 67   36   58

111    - 124 91   84

COMMENT -    H/S AT R92
```