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13. J. L. Rosenfeld taught me the geologic significance of the Black Mountain granite. I also thank Y. S. Nikhanj, P. Robinson, and D. R. Wones for advice in the field. Supported by NSF grant GA 4480.

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Land Clearance in the Irish Neolithic: New Evidence and Interpretation

Abstract. *Time scales are derived, from radiocarbon dating of pollen diagrams, for Neolithic land clearance at three Irish sites. Three stages are distinguished beginning in the 4th millennium B.C.: stage A, clearance and farming (possibly arable), 100 to 400 years; stage B, farming (possibly pastoral), 150 to 200 years; and stage C, forest regeneration, 50 to 100 years.*

Three radiocarbon-dated pollen diagrams from the north of Ireland are shown in Fig. 1. The sites studied were as follows: site I, Ballynagilly (*1*), and site II, Beaghmore (*2*), in County Tyrone; and site III, Ballyscullion, in County Antrim. The elevations of the sites above sea level are 640, 650, and 60 feet (195, 198, and 18 m). At sites I and II excavation has revealed evidence of Neolithic occupation adjacent to the deposits sampled: both sites are valley bogs. Site III, however, is a raised bog: it lies within a few miles of the diatomite flats of the Lower Bann Valley, intensively occupied in Neolithic and other periods (*3*). Radiocarbon dates for these sites, and for five others (*4, 5*) in Ireland, show that the beginning of the land-clearance phase, or the decline of elm pollen that usually accompanies it, falls between 5400 and 5000 radiocarbon years before the present, as in northwestern Europe in general.

The land-clearance phase at each site has been divided into three stages as follows: Stage A begins with a fall of forest tree pollen, usually elm and pine, or total tree pollen (as at site III), and is characterized by increased amounts of grass pollen and occasional plantain pollen. The overall amounts of grass pollen at site III are very low, but when the whole pollen diagram is inspected, rather than the section presented in Fig. 1, a definite increase is seen at the beginning of stage A. Stage A ends with a marked increase of plantain pollen. At sites I and II cereal-type pollen is present. Stage B begins with a marked increase of plantain pollen, which at sites I and III is accompanied by an increase of hazel pollen and a further decrease in the amount of elm pollen. Stage B ends when there is a relative increase of forest-tree pollen. This is taken as the beginning of stage C, which ends when the increase in the amount of tree pollen is complete.

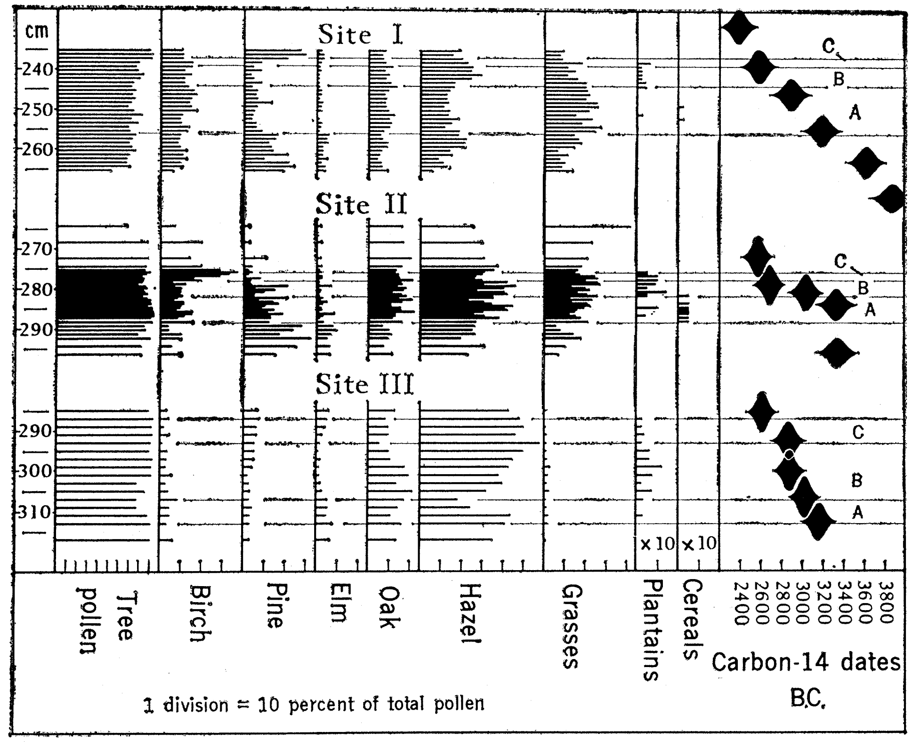
The radiocarbon dates (*5, 6*) are plotted in Fig. 1 as Gaussian curves (truncated at three standard deviations) (*7*) against the same depth scale used for the pollen diagrams. The curves give a visual indication of the probability distribution of the date measurements. Deposition rates shown by these graphs are: ~ 40 (± 10) year/cm at site I, ~ 35 (± 15) year/cm at site II, and ~ 15 (± 3) year/cm at site III. The precisions given are estimates only, derived by inspection. On the basis of these figures, the land-clearance phases appear to have lasted some 400 to 700 years.

A summary of the approximate age and duration of the three stages at each of the sites is given in Fig. 2. There are inherent difficulties in establishing an exact deposition rate and in dating the boundaries between the stages, because of the limited precision of the ^{14}C dates and the de Vries effect (*8*). The boundaries must not, therefore, be taken as fixed points in time. The time scale in Fig. 2 is in radiocarbon years: 1950 years have been subtracted for approximate conversion to the Christian calendar. In true calendar years, the beginnings of the land-clearance phases are likely to have occurred some 600 to 800 years before the time scale indicates (*9*). Although we show (in Fig. 2) stage A starting at different times for the three sites, the dates are derived only from the deposition rate curves and, within the limits of the method, could be contemporaneous. Unless there have been short-term fluctuations in the deposition rates, the durations shown for the stages are likely to be more precise than the dates for the individual stage boundaries.

Stage A apparently lasted 100 to 400 years. At site II cereal-sized grass pollen is present in nearly all samples. At site I also this stage has some cereal pollen. Plantain pollen is present, although sparse, at all three sites. On the basis of the presence of these cultural indicators, it seems that stage A was a farming period and that cereals were being grown. No cereal pollen was found at site III but, because of the poor dispersal of cereal pollen, the absence of crops in the vicinity need not be assumed. As has been shown in the experiments on primitive agriculture at Draved, in Jutland (*10*), even in the second year of crop growing the yields fall markedly. In view of the length of stage A, at least 100 years, we should perhaps envisage the continual opening of new ground.

Stage B appears to have lasted some 150 to 200 years. Cereal pollen is absent at sites I and II (it was present in stage A at both sites). Plantain pollen, which is generally accepted as an indication of prehistoric farming, is consistently present at all three sites. The differences between stages A and B, particularly at sites I and II, appear to represent some change of farming method. Plantain pollen is often regarded as evidence of pastoralism (*11*), and it appears possible, although it cannot be stated with certainty, that the emphasis changed from arable to pastoral agriculture. At sites I and III, and at Fallahogy, County Londonderry (*12*), the curve for hazel pollen rises sharply at the beginning of stage B. It

Fig. 1. Simplified pollen diagrams for Ballynagilly (site I), Beaghmore (site II), and Ballyscullion (site III), Northern Ireland, showing curves for major forrest trees and culture indicators as percentages of total pollen (alder has been omitted for site II). The curves for alder have been omitted; cereal and plantain values have been multiplied by 10, for the sake of clarity. Pollen sums are approximately as follows: site I, 500; site II, 200; and site III, 1200. On the right the ^{14}C dates are plotted as Gaussian curves on the same depth scale.



has been noted elsewhere (*13*) that cattle find hazel leaves unpalatable. Grazing would thus tend to increase the representation of hazel in the pollen diagrams.

Stage C, embracing the resurgence of tree pollen, appears to have lasted some 50 to 100 years. At the three sites this was clearly a stage of forest regeneration. At sites I and III the forests appear to have regained approximately their former composition and density. At site II, however, the regenerated forest seems to have had a larger birch component, perhaps the result of soil impoverishment.

At one of the sites a firm connection can be made between the farming and the material culture of the farmers. At site I the oak-plank wall of a rectangular house in a Neolithic occupation area gave a date of 3215 ± 50 B.C. (sample UB-201), and charcoal from a posthole inside the house gave a date of 3280 ± 125 B.C. (sample UB-199) (*2, 5*). These determinations are indistinguishable from the date of 3195 ± 70 B.C. (sample UB-253) for the deposit between 253 and 256 cm at the beginning of stage A (*5*).

Land-clearance phases of the type we have studied were first reported by Iversen (*14*), the Danish paleoecologist. Iversen was generally able to distinguish three stages: stage I, a stage in which the forest was opened, presumably by ax and fire; stage II, a stage of farming; and stage III, a stage of forest regeneration. He interpreted this sequence in some cases as a short episode of farming connected with slash and burn. The evidence from our sites suggests that the Irish land-clearance phases are not of this type, that is, "conditioned by a single occupation fire." Iversen also deduced that the deposits in large basins, where the changes in the pollen curves are smooth, reflected a more gradual change in the surrounding forest as a consequence of a whole series of new clearances. Such a sequence of events could have been the case at site III where our stages A, B, and C appear equivalent to Iversen's stages I, II, and III. Even here, however, there is a suggestion of the change of farming methods between stages A and B which is apparent particularly at site II. Stage A seems, in each case, to be equivalent to Iversen's stage I, but cannot reflect only the creation of a clearing. At sites I and II, in particular, the creation of clearings appears to have been rapid since the initial changes take place between adjacent samples. At Fallahogy, for which the stages determined by Iversen have already been described (*12, 13*), the radiocarbon dating showed that, as at the sites described here, the land-clearance phase was completed within a few hundred years. There was little to suggest, however, that the clearance and farming stages were not fairly short, of the order of years or decades. The data from this site are, however, equally consistent with the evidence presented here of prolonged periods of farming. The question now raised is whether, in the case of certain of the classical Danish Landnam phases, the relative shortness envisaged by Iversen (*10, 14*) will be confirmed by series of ^{14}C dates.

It will also be of considerable interest to see whether the different cultural phases of the Neolithic will be found

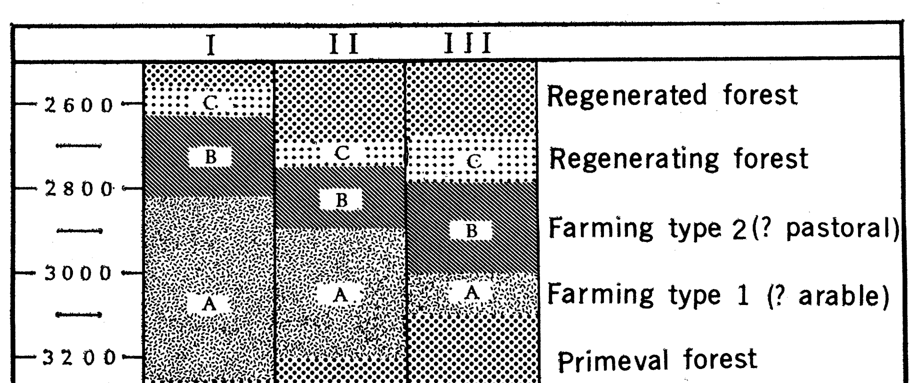


Fig. 2. Summary of land-clearance stages at Ballynagilly (site I), Beaghmore (site II), and Ballyscullion (site III), Northern Ireland. The scale on the left is the age in radiocarbon years less 1950 years. Boundaries between stages which are taken solely from deposition-rate graphs (Fig. 1) must not be taken as precise points.

to parallel the presumed change of farming economy between stages A and B. The surplus labor required for the construction of the great megalithic tombs could have been connected with a change to more productive farming methods such as might have happened in stage B. The oldest radiocarbon dates so far obtained from an Irish megalith are 2925 ± 150 B.C. (sample UB-318) and 2845 ± 185 B.C. (sample UB-319) for charcoal from soil beneath one of the satellite graves at Knowth, County Meath (*15*). Clearly much more dating, particularly of megaliths, will have to be done before any such connection can be established, and it is to be expected that different economic patterns will be demonstrated in different regions.

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Preparation of High-Crystallinity Polyethylene at Low Pressures

Abstract. *The preparation of highly crystalline polyethylene at low pressures is reported. With careful control of the substrate, the melting and crystallization schedule, and the physical state of the specimen (film thickness), it is possible to prepare polyethylene having a density in excess of 0.999 gram per cubic centimeter, a melting temperature of approximately 140°C, and a heat of fusion in excess of 70 calories per gram. The approach appears to be general and should be applicable to a wide variety of polymers.*

We report here the preparation at reduced pressures of polyethylene having a final melting temperature in excess of 139°C, a density in excess of 0.999 g/cm^3, and a heat of fusion, in the melting region, in excess of 70 cal/g. Although there is an extensive body of literature (*1, 2*) on the preparation of high-pressure crystallized polyethylene possessing both a high melting temperature (~ 140°C) and a high heat of fusion ($\Delta H_f \cong 70$ cal/g), few data exist to demonstrate the possibility of preparing such a high-crystallinity polyethylene at normal or reduced pressures (*3*).

We have paid particular attention to the method of sample preparation, especially the substrate (nucleating surface, the detailed thermal history, and the film thickness of the polyethylene. It has already been demonstrated (*4*) that the substrate has a profound effect on the interfacial properties of the polymer, as evidenced by changes in morphology (*5*), mechanical properties (*6*), and wettability (*5, 7*). In order to observe these effects it is imperative that the polymer thermodynamically spread (contact angle equals zero) on the substrate used to generate the polymer and that the substrate be removed from the polymer by dissolution rather than by mechanical means. When extremely thin sections are examined calorimetrically, the substrate may be left in contact with the polymer.

Two linear polyethylenes (unfractionated Marlex 6050 and a low-molecular-weight narrow fraction of Marlex 6001 with an average molecular weight of 10,000) were used in this study. A gold foil (0.5 mil, 99.999 percent pure) was used as the nucleating surface.

There is dual purpose in selecting gold as the nucleating substrate for polyethylene. Absence of an oxide coating not only aids in precluding oxidation of the polymer but also yields a polyethylene having the highest interfacial density (*5, 7*).

Polyethylene films between 0.2 and 1.5 mils thick were prepared by molding composites consisting of gold-polyethylene-gold at 1000 pounds per square inch (68 atm) and 170° to 200°C for 30 minutes. The composites were cooled rapidly by circulating water through the press platens. The rate of cooling was in excess of 20°C/min. Thin polyethylene sections (0.10 to 0.15 mil) were prepared by casting from a solvent a hot xylene solution of polyethylene (1.8 percent) on gold. The major portion of the solvent was evaporated above the melting point of the polyethylene in a nitrogen atmosphere. The gold-coated polymer was stored under vacuum for a minimum of 1 week to remove residual xylene. The final composite was formed by placing an additional piece of gold film on the polymer-coated foil and molding at 170°C for 30 minutes after which the composite was cooled according to the cooling schedule given above. Disks consisting of gold-polyethylene-gold composite (0.634 cm in diameter) were punched out with a special die for use in the differential scanning calorimeter (Perkin-Elmer model DSC-1B). The samples were heated and cooled in a programmed fashion under a reduced nitrogen pressure. Specimens prepared at atmospheric nitrogen pressure showed slight signs of oxidation, as evidenced from an infrared examination. The use of a reduced pressure of nitrogen (0.25 mm-Hg) is sufficient to preclude the oxidation noted in our earlier experiments. The results reported here are for polyethylene prepared at reduced pressures.

The differential scanning calorimeter was modified with a repeat cycle timer (G. C. Wilson and Co.) to extend the rate of heating or cooling of the specimens from 0.625°C/min to 0.001°C/min. The density gradient column contained a mixture of diethylene glycol and isopropyl alcohol (1 : 1), which was maintained at 23°C and 50 percent relative humidity.

The thickness of the samples was measured with an electronic micrometer (J. W. Dial & Co.) and also calculated from the dimensions, the weight of the sample, and the measured density. When the density was not measured, an arbitrary value of 0.975 g/cm^3 was used. The film thicknesses