Soil Phosphate Measurements: problems and possibilities

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Paper presented at the conference "Geophysical and Geochemical Prospection in Archaeology 1986", Bradford, England, 7th. to 9th. January, 1986.

Synopsis of "Soil Phosphate Measurements: problems and possibilities. Part 1", by Helen C.M. Keeley.

Soil phosphate analysis is used widely in Europe and the USA in archaeological site investigations. Provided soil conditions are favourable and post-occupation land use has not obscured "ancient" phosphorus distribution, the technique can be used successfully to delineate and differentiate between man-associated activity areas.

Phosphate survey has been used in the U.K. as a prospection method with some success at a number of locations, e.g. at Fengate, Peterborough, where a previously unsuspected Iron Age settlement was revealed at the Cat's Water subsite, although at others local soil conditions have proved unfavourable, e.g. low pH and waterlogging at Haddenham, Cambs. Magnetic susceptibility measurements complement phosphorus analysis because enhancement of the former is linked to areas of burning while the latter indicates rubbish, excretion and the remains of bodies. As in Britain, soil phosphate surveys have been used in the Netherlands with varying degrees of success. The range of chemical methods for phosphorus analysis has been supplemented in Holland by the visual examination technique, due to the particluar nature of certain clay soils.

Soil phosphorus analysis appears to be most useful in archaeological prospection when other techniques, such as aerial photography and standard geophysical surveys, are less appropriate, for instance where archaeological features are overlain by clay deposits as at Fengate and Assendelft. It can also be used cost-effectively to confirm and complement conventional archaeological survey work if a rapid analytical method is employed. However, results will depend on soil type (and land use) and problems may occur in areas of light, sandy soils or under acid reducing conditions. It must also be borne in mind that the general archaeological approach to soil phosphorus analysis has, to date, been extremely empirical and that many interpretations have been simplistic in the extreme and this aspect forms the subject of the second part of this paper.

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Soil Phosphate Measurements: problems and possibilities.
Part 1: The Use of Soil Phosphate Analysis in Archaeology.
By Helen C.M. Keeley.

INTRODUCTION

The phosphorus (P) contents of most mineral soils falls between 0.02 and 0.5% P. About half the soil phosphorus occurs in combination with the topsoil organic matter and the remainder as minerals or in inorganic combination (Bear, 1964). Inorganic phosphorus is held in combination with calcium (Ca), iron (Fe), aluminium (Al) and titanium (Ti) and perhaps with soil colloids. In neutral and calcareous soils the dominant bonding is to Ca (dicalcium phosphate, octacalcium phosphate and the apatite series of minerals are formed); in acid soils most phosphorus is combined with Fe and Al (Cooke, 1967). Because of these "fixation" reactions, soluble phosphate fertilizers are not easily lost from most soils, although there is a risk of leaching on some light, sandy soils and during conditions of waterlogging.

In applying soil phosphorus analysis to archaeology the basic assumption is made that the detritus produced by the activities of man and his domestic animals is rich in phosphorus which is not easily dispersed by soil action, even over long periods of time. Consequently soil testing for the presence of phosphorus offers the possibilty of locating ancient settlements and studying the composition of archaeological deposits. This has been recognised and a considerable body of work has built up relating to archaeological soil phosphorus (reviewed in numerous articles, e.g. Schwarz, 1967; Provan, 1971; Eidt, 1973; Proudfoot, 1976; Sjöberg, 1976; Woods, 1977; Eidt, 1977; Bakkevig, 1980; Zölitz, 1980; Keeley, 1981, 1983; Eidt, 1984; Gurney, 1985).

THE USE OF SOIL PHOSPHATE ANALYSIS IN ARCHAEOLOGY

Workers in this field have been much concerned with methods of analysing soils for phosphorus and various field and laboratory methods have been devised. Initially methods were borrowed directly from soil science (e.g. Chang and Jackson, 1957), which is more concerned with the agricultural rather than archaeological implications of phosphorus concentrations in soils. However a number of workers have produced methods of soil phosphorus analysis for archaeological purposes, initially with an emphasis on rapid testing in the field rather than relatively time-consuming laboratory methods.

The work of Lorch (1939,1940) and Gundlach (1961) provided a basis for the development of a simplified field test for phosphorus by Schwarz (1967) in Switzerland, which was further modified in the USA by Eidt (1973) and found useful not only for mapping horizontal phosphorus distribution (e.g. settlement boundaries) but also for ascertaining the vertical extent, i.e. the relative duration of settlement activities. The method comprises an acid extraction (hydrochloric or nitric) followed by a colorimetric determination (molybdenum blue) and is at best semi-quantitative.

Phosphorus analysis has been widely used in Scandinavian archaeology, Arrhenius being one of the first to notice the relationship between phosphorus in the soil and sites of human occupation and successfully locating ancient settlements (Provan, 1971). It is rused as a standard survey method in Norway (Bakkevig, 1980) and Sweden (Sjoberg, 1976). Although extensively used in parts of Europe and the USA (e.g. Woods, 1984), phosphorus testing of soils has only found favour relatively recently in British archaeology.

The technique is used in two ways:

1. Investigation of individual sites

Phosphate testing of known archaeological sites is carried out to solve specific problems, e.g. delineation of rubbish disposal areas, location of places where livestock were kept, inhumations in acid soils, investigation of manuring practices, etc. Total phosphorus was measured in deposits of a tell at Sitagroi (NE Greece), the tell having 11m. depth, 180m. diameter and representing 5 major occupation phases with a time span of about 5,400 to 2,200 calender years BC (Davidson, 1973). In this case total phosphorus was measured colorimetrically after fusion with sodium carbonate. Samples from the tell contained much more phosphorus than surrounding soils and concentrations were higher in later deposits, indicating an increase in intensity of occupation. Using a field 'spot' test (Schwarz, 1967), Keeley (1981) has achieved approximately 60% success in minor archaeological phosphate investigations. The 'spot' tests are crude but can be used to indicate the best areas for follow-up quantitative analysis.

Total phosphorus analysis (Dick and Tabatabai, 1977) was used to investigate a prehistoric enclosed settlement on Shaugh Moor, Dartmoor (Balaam, 1980). This enabled areas of waste disposal and possible drainage outfall to be delineated and indicated that animals were excluded from the domestic area. Studies of soil phosphorus at the Cefn Graeanog (Gwynedd) farmstead site (White, forthcoming), which was occupied from the Iron Age, through the Roman period and into the Dark Age, enabled Conway (1983) to suggest that animals were being tethered in one part of a Romano-British hut.

Similar investigations are being carried out on many archaeological sites in the U.K. and success depends largely on soil conditions and post-occupation land use, e.g.fertilizer applications. Problems are most likely to be encounterd on acid sandy soils where phosphorus has been physically or chemically moved down the profile and, sometimes, lost from the soil. Downward movement of clay and silt fractions (which usually have much higher phosphorus contents than the coarser fractions) in sandy soils can lead to phosphorusP movement (Zolitz, 1980), especially where there is a large proportion of coarse and medium soil pores (pore diameter >0.2mm.). Heavy applications of modern phosphate fertilizers may obscure soil phosphorus variation related to archaeological features, as found at the sites of Mucking (multi-period) and Kelverdon (Iron Age), Essex (Keeley, 1981).

2. Archaeological Prospection

The first major use of phosphate survey in the U.K. was over the 93 acre site at Grimes Graves, Suffolk (Sieveking et al, 1973), with the object of locating the occupation debris of the prehistoric flint mines. A field method of phosphorus analysis was developed to provide semi-quantitative data rapidly for large numbers of samples. Known Roman, Medieval and post-Medieval occupation sites were located but no Neolithic was found, because there had been no concentrated occupation of the site during this period (Craddock et al, forthcoming). Clarke (1977) compared magnetic susceptibility and phosphorus analysis (using the method of Sieveking et al, 1973) for prospection at Tadworth, Surrey, on an Iron Age 'banjo' site (chalk bedrock). Both surveys revealed areas of enhancement largely coincident with the enclosure but were almost mutually exclusive, in that susceptibility was associated with the central living area (burning) and phosphorus with the annexe - presumably where animals were kept and their excreta accumulated.

At Fengate, near Peterborough, a phosphate survey on the Cat's Water subsite revealed a completely unsuspected Iron Age settlement (Craddock, 1984), consisting of at least 55 buildings with numerous associated ditches and wells, obscured from aerial photography by Roman flood clay, although topsoil phosphate generally reflected concentrations beneath. Phosphate samples were taken from the subsoil surface at Newark Road, Fengate (Craddock, 1980) - pH 5.5 to 6.5 - and higher phosphorus concentrations (presumably derived from animals) were found associated with a drove way than in the surrounding enclosure, indicating considerable livestock traffic.

Evidence from Fengate and Tadworth indicated that the phosphorus content of undisturbed archaeology is reliably reflected in the topsoil above, so that for locational work only the ploughed soil surface need be sampled, the effect of ploughing being to disturb rather than to destroy the archaeology (Craddock et al, forthcoming). At Maxey, Cambs., on a broad low gravel ridge in the Welland valley, the well-known multiperiod cropmark site was surveyed by fluxgate gradiometer, followed by soil sampling (for phosphate and magnetic susceptibilty determinations) on a 5m. grid (Clarke, unpublished). Two areas of general phosphate enhancement were found, one associated with an Iron Age settlement and probably derived from rubbish, the other in an area blank of features probably resulting from livestock, and results could be related to features later found by conventional excavation (Gurney and Craddock, 1981).

However at Haddenham, Cambs., soil phosphorus concentrations were found to be very low and unrelated to human activity (Hodder, pers. comm. 1982). Soil pH is very low in this area (4.5 to 5) and rapid loss of phosphorus from fertilizer inputs is a common agricultural problem (Evans, pers. comm. 1982) in the Fens below soil pH 5, associated with areas of acid peat and fen clay. In waterlogged soils a considerable amount of phosphorus may be mobilised and removed from the profile in the groundwater (Bear, 1964; Zölitz, 1980).

In the course of 10 years' work Craddock et al (forthcoming) have analysed more than 20,000 soil samples from 15 sites in the U.K., varying from Neolithic to Medieval in date, and concluded that phosphorus analysis cannot compete with aerial photography or field walking as a survey technique over large areas but gives best value as a locational technique for detailed survey of smaller specific areas of interest.

In the Netherlands phosphate surveys are carried out by visual examination of the subsoil, e.g. at the multi-period rural site of Wijk bij Duurstede (van der Voort et al, 1979), by looking for green and red phosphate stains in auger borings. In the Kromme Rijn region using a visual examination phosphate survey, in conjunction with noting presence or absence of artifacts (e.g. ceramics) and dark humic layers, areas of human settlement have been outlined associated mainly with levee soils (Poelman, pers. comm. 1982). This technique is thought by many Dutch archaeologists and soil surveyors to be a useful method of archaeological survey, applicable to large areas of suitable clay soil types in the Netherlands. However it is likely to have little, if any, application in British archaeology.

During the Assendelft Polder project, north-west of Amsterdam, auger samples were tested in the field by the method of Eidt (1973), which was found to be useful in delineating settlement areas (Brandt, pers. comm. 1982), many of which were obscured from aerial photography by a medieval clay layer.

Attempts have been made to use fractionation techniques to distinguish human phosphorus deposition from natural soil phosphorus and to identify types of features and land use (Woods, 1977; Eidt, 1977 and 1984). Eidt (1977, 1984) suggested that his rapid field test should be used initially to identify settlement areas, followed by a phosphorus fractionation method, based on that of Chang and Jackson (1957), on selected samples. This method is supposed to distinguish between "natural" phosphorus and "human" phosphorus, and conclusions relating to land use are drawn from the distribution of phosphorus in the various fractions.

It is certainly true that the archaeological approach to soil phosphorus analysis has been, to date, very empirical. Little attention has been paid to other soil factors and simplistic interpretations are drawn from what must be extremely complex soil environments. This important subject will be considered in the second part of this paper.

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