TRACING RECHARGE WATER TO POROUS COLLUVIUM IN ARCHAEOLOGICAL SITES*

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Fluorescein dye tracing can be used to demonstrate or negate a hydrogeological connection between a coal strata and a porous rockshelter colluvium. These data have important implications for the determination of source areas for achaeological charcoal contamination by coal.

INTRODUCTION

Chemical and physical weathering of coal releases both particulate coal and volatiles which are dissolved or suspended in and transported by groundwater. Therefore, coal has been suggested as a source of contamination in radiocarbon samples from archaeological sites (Tankersley, 1983; Tankersley *et. al.*, 1984), in particular one of the apparently oldest rockshelter sites in the Eastern United States (Haynes, 1980, p. 585). Stuckenrath (1977, p. 183) has emphasized that the sample collector should initially assess the possibilities and probabilities of radiocarbon sample contamination. One method to determine coal contamination is analysis of the isotopic composition of the archaeological radiocarbon sample, the coal source area, and the groundwater (Coleman, 1976). Such isotopic studies are costly, however, and more importantly consume a significant quantity of archaeological carbon, which may exist only in very small amounts. This paper describes a field method to determine whether or not groundwater which flows over or through coal deposits can be traced to archaeological deposits.

STUDY PROBLEM

In the Eastern United States, rockshelters (or caveshelters) provide the archaeologist with dry conditions which enhance preservation of organic materials. Rockshelters have always been important sites of human activity throughout prehistory because they provide semi-enclosed habitation areas that are protected from the weather. Additionally, they are archaeologically important because they often contain relatively undisturbed stratigraphy resulting from weathering and colluvial deposition of the overhanging rocks and deposition of human origin. Rockshelter development commonly occurs at the base of cliff exposures along retreating Pennsylvanian sandstone escarpments and stratigraphic outliers. These geographic areas coincide with bituminous coal strata and often have a common source of groundwater. Volatile organic matter released from the coal by the natural chemical and physical weathering processes are frequently dissolved in and transported by groundwater which recharge in porous rockshelter colluvium. For example, ground water passing through a mined coal exposure or natural outcrop can enter the porous colluvium of a rockshelter through the following hydrogeological processes:

1) percolation of groundwater through bedrock capillaries and fractures which recharge within the rockshelter, either on the ceiling or walls or at the interface of the rockshelter wall and colluvium.

2) discharge of groundwater above the rockshelter, enters the colluvium at the dripline, and percolates through these deposits.

3) a coal stratum in the rockshelter's wall acts as an aquifer in formation of springs above or within the colluvium.

Reynolds (1966) has shown that fluorescent dyes can be used to trace percolation water. This study used fluorescein dye to determine if two of the hydrogeological processes can be traced. The third process can be recognized by identifying the petrological composition of the rockshelter—dye tracing is not necessary. Injection and detection methods are described for tracing these other two processes.

INJECTION

Fluorescein's limitations of photostability, pH-controlled structural change, and adsorptive losses necessitate several simple precautions to be taken before dye injection. However, these limitations do not inhibit fluorescein's suitability for tracing percolation water in sandstones.

Smart and Laidlaw (1977, p. 15) have noted that fluorescein has high visibility in low solution concentrations but poor stability under sunlight. Therefore, it is necessary to

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keep the dyed surface water to a minimum. This can be accomplished by injecting the dye at the stream's locus of complete disappearance. Upland escarpment streams are often intermittent making spring the preferable time of the year for successful dye tracing. The locus of stream disappearance in the spring will generally be closer to the rockshelter, thus reducing the sorptive loss of fluorescein. The locus of stream disappearance is usually associated with stream ponding creating an ideal injection site.

Iron sulfide (pyrite) inclusions in bituminous coal form sulfuric acid in surface runoff. Fluorescein structurally changes to a leucocompound in highly acidic streams of coal mining areas. However, stream acidity decreases with its distance from the coal source area and fluorescein's structural change can be reversed in the test by an alkaline solution.

Simple precautions against adsorptive dye loss onto sediment and bedrock surfaces should be taken, although sandstones are poor inorganic adsorbents and fluorescein is relatively resistant to humus adsorption (Smart and Laidlow 1977, p. 27). It is recommended that a minimum of 1000 ml of fluorescein powder (600 mesh or finer) be used for a first order stream. The fluorescein should be wrapped in a gauze or coarse fabric, tied, weighted with a lead fishing weight, and placed in the injection site. The fabric helps prevent immediate organic adsorption (keeps the fluorescein clean), provides a "time release" mechanism, and the great volume of fluorescein guards against complete adsorptive dye loss during percolation.

DETECTION

The rate of percolation volume per time ‡ space varies from locus to locus making activated charcoal adsorption traps necessary. Approximately 50g of activated charcoal (a double handful) contained in a finely-meshed nylon fabric (nylon stocking) is perfectly suited for the recovery of dyed recharge water in porous rockshelter colluvium. The nylon fabric is resistant to short-term decay and prevents an initial physical mixing of the charcoal with the sand, silt, and clay of the colluvium. Suitable places for recovery traps in colluvial deposits may be damp spots along the dripline, near the rockshelter wall, and in areas near springs. At all locales the charcoal adsorption traps should be placed in the colluvium to a depth which permits the surface area of the charcoal to be completely exposed to percolation water. If several potential contamination locales exist within the rockshelter, all locales should be tested in order to assess and reconstruct the hydrogeological processes which affect archaeological carbon.

Adsorbed fluorescein dye can be retrieved from the charcoal with a standard alkaline solution of 10% potassium hydroxide and ethanol. An acceptable percolation time will be dependent upon the distance between the injection and detection sites and the relative abundance of capillaries and fractures in the bedrock. After the trap has been removed from the colluvium the charcoal should be placed on a piece of filter paper at the bottom portion of a petri dish (9 cm in diameter). The alkaline solution can then be poured into the petri dish dampening the filter paper and releasing the adsorbed fluorescein dye from the charcoal, if it is present. If the concentration of fluorescein is too low to be detected in visible light, then a portable ultraviolet lamp can be used to excite the dye. Fluorometric analysis is not necessary since the nature of this experiment is to demonstrate the presence or absence of fluorescein in the recharge water establishing a groundwater connection between a coal outcrop and rockshelter colluvium.

SUMMARY

Coal volatiles in groundwater represent a potential radiocarbon contaminant of archaeological charcoal in rockshelters in the Eastern United States. Archaeologists have a responsibility to recognize the hydrogeological processes that can transport radiocarbon contaminants to a charcoal sample. Fluorescein dye tracing provides an effective means of demonstrating whether or not there is contact between groundwater in coal source areas and rockshelter deposits.

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