# Charcoal Analysis of Varved Lake Sediments

Charcoal analysis of varved lake sediments can provide a detailed record of local fires. The close chronological control offers the possibility of correlating fire occurrence with slashandburn land clearance, as shown by Tolonen (1978) in southern Finland and Clark *et al.* (1989) in southern Germany. The method is more informative if the stratigraphic analysis is made on petrographic thinsections of varved sediment impregnated with epoxy. The abundance of large charcoal particles can be determined yearbyyear under low magnification and transmitted light. This method is superior to that in which particles of all sizes are counted on pollen slides, for large particles may be broken in the preparation of the pollen slides, and small particles may also come from unidentified distant sources.

As originally developed by Merkt (1971), the thinsection method involves freezedrying a strip of sediment with liquid nitrogen under vacuum, followed by impregnation with epoxy resin, which is insoluble in water. Petrographic thinsections are cut to a uniform thickness of about 30 microns. Because freezedrying may cause cracking or other deformation of the varves, an alternative method for dehydrating the sediments involves the replacement of the pore water by acetone (through several exchanges over many days), followed by replacement of the acetone by epoxy resin (Clark, 1988a).

The efficacy of the thinsection technique in determining fire occurrence is illustrated by a study of charcoal abundance in a sequence of several hundred varves in three nearby lakes in Itasca State Park in northwestern Minnesota (Clark, 1990). The initial objective of this study was to correlate the charcoal abundance with the firescar record on old trees of *Pinus resinosa* located within the catchments of the three lakes, as well as to relate the inferred fire frequency to the instrumental weather record of the past 150 yr. The analysis could then extended to depth to determine the fire frequency under earlier climatic conditions.

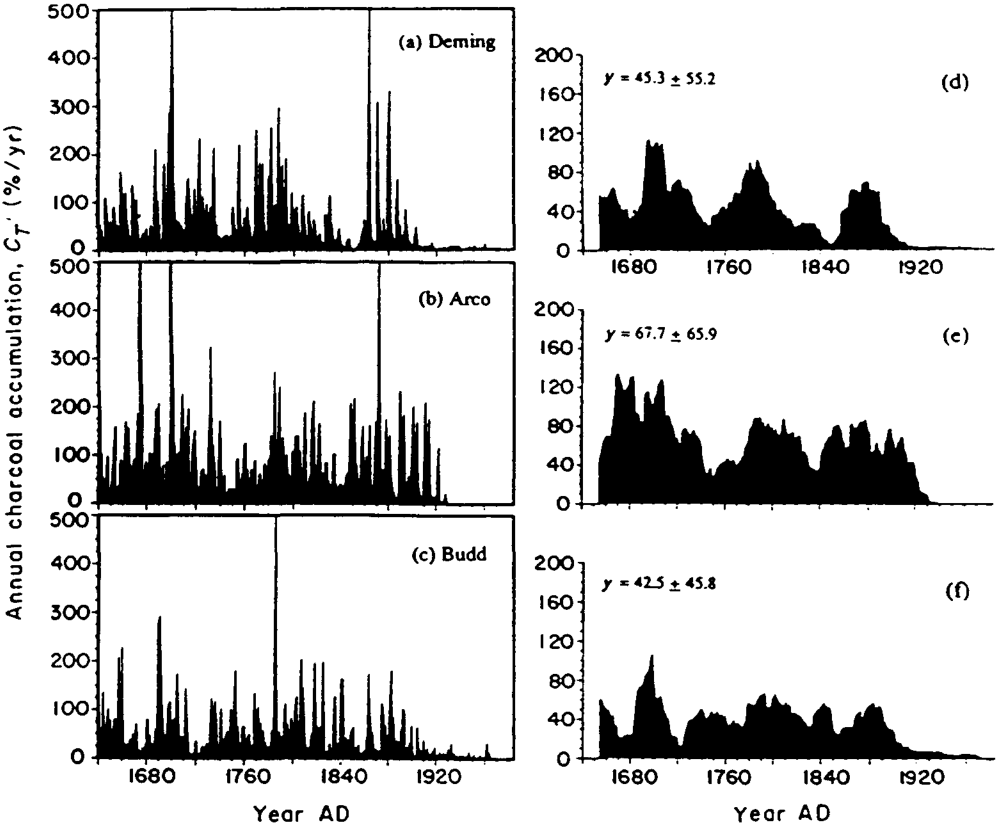


*Fig. 1. Charcoal index for varved sediments from three small lakes in northwestern Minnesota since A.D. 1640. Histograms on the right are smoothed with a 15yr running mean. Note the very low values since A.D. 1910, when fire suppression prevailed. From Clark (1990).*

Because the area was never cleared for agriculture in prehistoric time and has been subject to essentially no timbercutting, the forest could be considered as natural. On the other hand, total suppression of fire has been a policy since 1910, and forest succession since that time has proceeded without influence of the recurring fires to which it had been adapted. These relations are documented and the effectiveness of the thinsection method demonstrated by the fact that the varves since 1910 contain virtually no charcoal (Fig. 1). Prior to this date the charcoal index (percent of varve surface covered by charcoal) fluctuated over time, and individual peaks are matched by fire scars on pine trees in the catchment or nearby (Fig. 2), indicating that large charcoal particles come from local fires small particles come from distant fires of unknown source and can be ignored.

When smoothed the histograms of the charcoal index plotted against time for all three sites (Fig. 1) show maxima about A.D. 1890, 1900, and

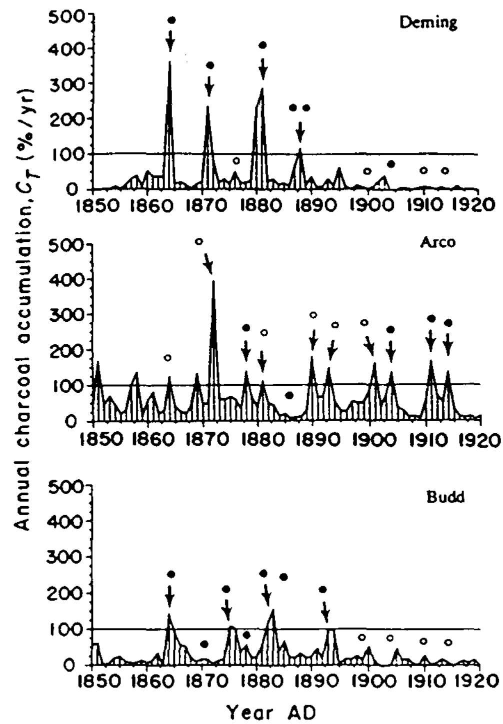


*Fig. 2. Charcoal index for varved sediments at the three lakes A.D. 1850-1920, showing also the dates for fire scars on pine trees within the particular catchment (closed circles and values above C = 100) or nearby catchments (open circles). From Clark (1990).*

1710 (thus about every 90 yr.) and at earlier times at intervals about half that amount. Measurements of varve thickness show the same maxima (Fig. 3), and analysis of ignition loss indicates that thick varves can be attributed to increase in the mineral component (Fig. 3). The greater varve thickness and greater mineral content during the 1930's (when fire suppression kept the charcoal index near zero) suggest that erosion of shore sediments was enhanced as a result of lower lake levels, for the instrumental weather record for Minnesota indicates markedly reduced precipitation at this time (Fig. 4).

The relationships between climate, low lake levels, shore erosion, varve thickness, charcoal index, and fire scars form the basis for explaining the reduction in the smoothed frequency of charcoal maxima from 90 yr in recent centuries to a shorter duration at earlier times (Fig. 5). The time span when the 90yr intervals prevailed corresponds to the Little Ice Age, when the climate was cooler and moister than it is today, as indicated not only by the expansion of glaciers in the western mountains (Leonard, 1986) but also by shifts in the forest composition in southern Minnesota (Grimm,

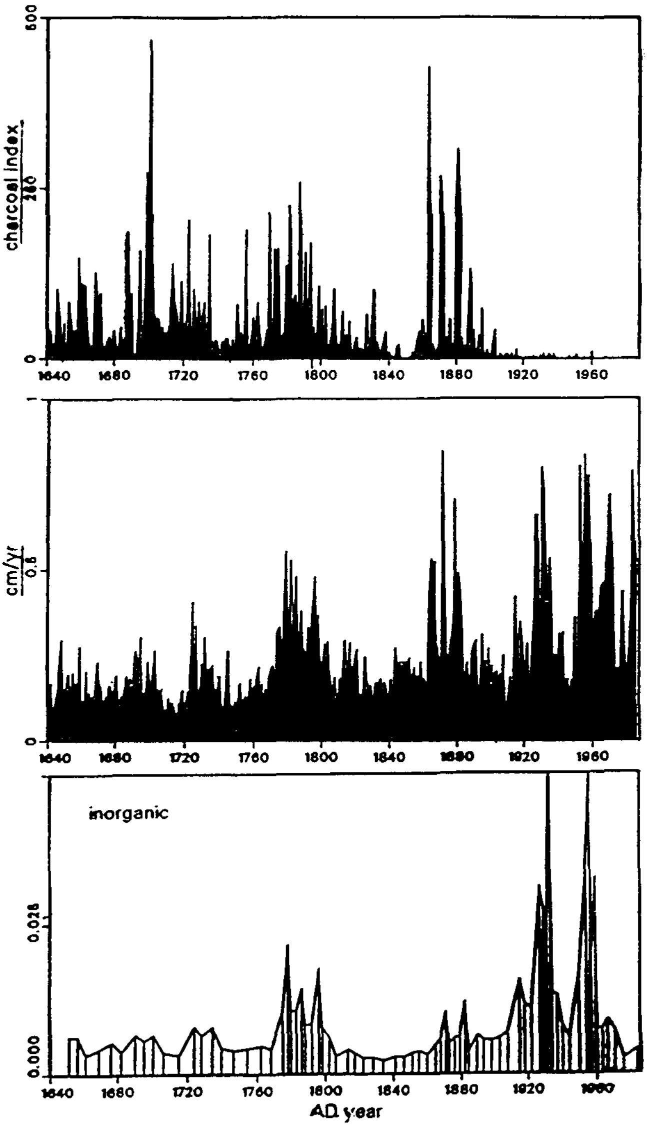


*Fig. 3. Charcoal index (top), varve thickness (middle), and percent organic matter (bottom) for Deming Lake A.D. 1640-1980, showing correlation of inferred fire maxima with inferred increases in shore erosion.*

1983). The interval of 90 yr approximates the longevity of the trees that commonly succeed after fire in this region (principally *Populus tremuloides* and *Betula papyrifera*, as well as later successional *Abies balsamea)*, and the buildup of fuel provided by the dying trees increases the chance of fires strong enough to produce the charcoal maxima (Clark, 1988b). A cyclic rhythm is thus established, perhaps tuned to multiples of the sunspot cycle that may control the frequency of droughts. During the relatively warm/dry climatic phase before the Little Ice Age, the drier condition of fuels led to shorter intervals between major fires.

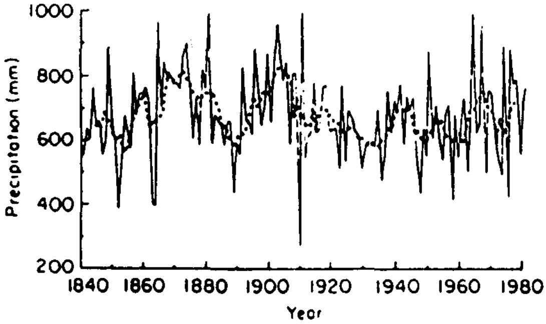


*Fig. 4. Instrumental record of precipitation minus evapotranspiration for Minneapolis, Minnesota. Note the droughts of the 1930's and late 1880's. From Clark (1989).*

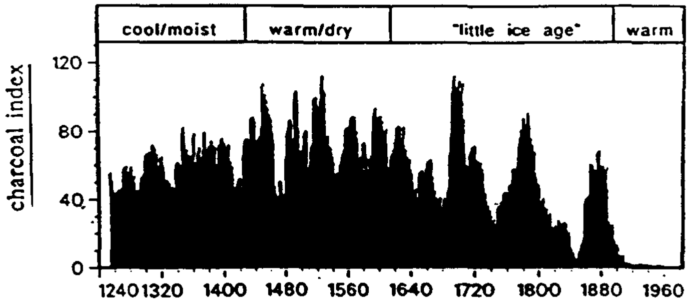


*Fig. 5. Charcoal index for Deming Lake (smoothed with a 15yr running mean) since A.D. 1240, showing spacing of maxima at ca. 90 yr during the Little Ice Age and about half that amount during the preceding warm/dry interval. From Clark (1988b).*

In much of Europe natural fires are believed to be uncommon. Stratigraphic analysis of large charcoal particles in varved sediments by the thinsection method provides a technique for documenting slashandburn land clearance on a spatial scale comparable to that relevant in other techniques for evaluating human impact, e.g. pollen stratigraphy, palaeomagnetic profiles, and records of soil erosion. High charcoal abundance in the absence of such indications of human disturbance must be considered as natural, thereby providing the opportunity to evaluate by pollen analysis the course of natural forest succession after fire.

H.E. WRIGHT, Jr. and J.S. CLARK
Department of Geology and Geophysics
University of Minnesota
USA - 55455 MINNEAPOLIS-MINNESOTA

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