Radiocarbon Dating the Artificially Contained Surfaces of the Rhône Deltaic Plain, Southern France

Daniel Jean Stanley

Deltas-Global Change Program
Paleobiology, E206-NMNH
Smithsonian Institution
Washington, DC 20560, U.S.A.

ABSTRACT

SURFICIAL sediment surfaces of various world deltaic plains are commonly radiocarbon dated to over 2000 years before present (BP), rather than to a modern age. In the present investigation of the Rhône plain, southern France, surficial sediments that record anomalously old dates (to >4000 BP) occur preferentially on flooded surfaces where old carbon has accumulated. This old carbon is a component of recently eroded, fluvially-derived sediment that has been redeposited farther downvalley. In contrast, most radiocarbon-dated samples (plant and organic carbon) from artificially contained surfaces on the Rhône plain are of modern age. Modern radiocarbon dates prevail at artificially diked localities where (1) soil layers form on plain surfaces that are not periodically buried by flood deposits, and (2) accretion rates of recently deposited sediment incorporating reworked old carbon are minimal.

Modern radiocarbon dates obtained at the Rhône deltaic plain provide chronostratigraphic markers against which Holocene dates from subsurface strata can be compared and spurious dates eliminated. The presence of such dates at many sites also provides a means with which to measure recent movement of land surfaces relative to sea level. Reliable dating of surficial sediment on artificially contained surfaces is one of the critical measures needed to help plan realistic protection for lower-lying sectors of the Rhône delta in danger of inundation.

ADDITIONAL INDEX WORDS: AMS dating, cores, dikes, floods, Holocene deltas, impounded surfaces, old carbon, overbank deposition, remobilization, sea-level rise, sediment storage, subsidence.

INTRODUCTION

Accurate dating of sediment in surficial sections and in borings is a critical element for developing a reliable late Holocene stratigraphic record for modern world deltas and for interpreting their geological evolution. In this respect, surficial sediments forming the recent plains of world deltas would presumably record modern dates. However, studies of various Holocene deltas have shown that radiocarbon dates obtained at deltaic plain surfaces are often too old and, moreover, dates in subsurface sections commonly fail to record a consistent progression of younger dates upsection. Some radiocarbon dates, for example, are as much as 2000 to 4000 years before present (BP) at and near the present surface plain of the Mississippi (McFarlan, 1961), Ganges-Brahmaputra (Banerjee and Sen, 1987), Yangtze (Yan and Xu, 1987), Nile (Stanley et al., 1996) and Rhine-Meuse (Törnqvist et al. 1998) deltas.

To gain further insight regarding this phenomenon of anomalously old radiocarbon dates, the present study examines a suite of Holocene samples collected on the modern surface of the Rhône deltaic plain. This low-relief surface, positioned between the delta apex north of the town of Arles and the delta margin along the Mediterranean Lion Gulf coast of southern France, comprises an area of approximately 1500 km² formed of alluvial, wetland and nearshore environments (Figure 1). The Rhône subaerial plain was specifically selected for examination because many sectors have been contained by dikes and artificial levees over a long period, thus producing large areas of non-flooded, subaerially exposed surfaces with diminished accretion of new fluvial sediment (Hensel et al., 1999). These artificially contained areas have formed an increasing portion of the deltaic plain during the past several centuries (Rapport Camargue, 1970; Corre, 1992).

Although many environmental aspects of the Rhône system have been studied, there is as yet little available information on radiocarbon dates of uppermost and surficial sediments in this vulnerable, low-elevation setting (Oomkens, 1970; Aloisi et al., 1978; Leveau and Provansal, 1991; Gensous and Tessson, 1996). The present investigation serves to determine if radiocarbon dates collected on the Rhône plain surface could be used as temporal markers to help measure the motion of upper Holocene land sections of the delta relative to sea level.

METHODS

Eighteen surficial sediment samples were collected at a depth of 0–10 cm for radiocarbon dating at 16 sites located across the Rhône deltaic and coastal plains. Positions of the 16 sites where deltaic and contiguous coastal plain samples were recovered are shown in Figure 1. Samples were selected on-site on the basis of high organic content, most specifically
black color and preservation under reducing conditions. Three sites (1-3) are located east of the Grand Rhône, five (4-8) are between the Grand and Petit Rhône distributaries, six (9-14) are between the Petit Rhône and Vidourle River, and two (15, 16) are positioned on the delta’s western margin, along the Mauguio lagoon.

Mean grain size, total organic carbon (TOC), 13C/12C ratio, and conventional radiocarbon age (uncalibrated) results for the 18 samples at the sixteen sites (including 2 splits at sites 1 and 9) are listed in Table 1. The organic carbon fraction disseminated in the fine sediment (<63 μm) of 15 samples was dated by conventional radiocarbon analysis (acid pretreatment) by Beta Analytic Inc., Miami, Florida. At sites 1 and 9, sample cuts of both fine disseminated organic carbon and fibric matter were dated separately. Moreover, two cuts of the sample at site 9 were dated by accelerator mass spectrometry (AMS) at the NOSAMS facility, Woods Hole Oceanographic Institution, Massachusetts.

The results are reported in Table 1 as percent modern carbon (pmc) where finite ages were not derived. The designation ‘modern’ typically refers to an age that is less than 190 radiocarbon years, although in some instances, modern ages in the present study may range as far back as 300 years (cf. Stuiver and Polach, 1977). Modern results close to 100 pmc could allow for ages as much as 300 years old (~1650-1950AD) due to recent fluctuations in the atmospheric radiocarbon concentration. Modern values well above (more than two sigma above) 100 pmc demonstrates the presence of bomb carbon generated within the last fifty years, representing very recent material (D.G. Hood and M. Tamers, January, 2000, personal communication).

**OBSERVATIONS**

Fourteen of the 18 dated Rhône surficial samples (~78% of the database) record a modern age (Table 1). These 14 samples were collected on artificially altered surfaces at 12 sites. Ten of the sites are located on impounded areas of deltaic plain (Figure 1), including wetland areas near the Vaccarès lagoon and surfaces positioned on and near former branches of the Rhône (cf. L’Homer, 1992; Arnaud-Fassetta and Provansal, 1993). The sample at site 6, with a 13C/12C ratio of ~15.8‰, appearing more enriched than the other samples, was collected in a recently dried, organic-rich lagoon. Also dated as modern are the two samples from the Mauguio lagoon margin. Mean grain size of the samples dated as modern ranges from 36 to 195 μm (coarse silt to fine sand), and TOC ranges from ~6% to ~33% (average ~25%). These samples, that include large proportions of both sapric (i.e. humus, including fine-grained particulate and dissolved organic mat-
ter) and fibric (coarse-particulate) material, differ markedly from typical deltaic plain surfaces that contain a low TOC (cf. Hensel et al., 1999).

Of the four pre-modern samples (~22% of database), the oldest (site 1), dated at 4400±50 years BP, was collected on the east bank of the Grand Rhône near the Canal de Meyranne. Two other samples were also collected east of the Grand Rhône, one at site 3 near its mouth at Thé de Rousstan (1620±70 years BP) and the other at site 2 along the eastern delta margin near the Marais du Retour (1640±40 years BP). The sample at site 12, recovered along the Rhône delta—upland (Costières Terrace) margin east of the Vidourle River, near les Cadenets, was dated at 840±60 years BP. Mean grain size of the four samples ranges from 37 to 63 μm (coarse silt), and TOC ranges from ~8 to ~17% (average ~14%).

Of note are the two ages obtained from the sample at site 1: the fine-grained organic carbon fraction was dated at 4400±50 years BP, while the separately dated plant debris fraction recorded a modern age. At site 9, the finely disseminated organic carbon and plant debris fractions were dated separately by AMS, and at this locality both fractions record a modern age (Table 1, Figure 1).

**DISCUSSION**

Radiocarbon dates from subsurface Holocene sections in the Rhône delta indicate that some ages are both older than expected and inverted (older upsection; Oomkens, 1970) rather than in correct stratigraphic position (i.e. systematically younger upsection). Here, as in other deltas such as the Nile, Yangtze and Ganges-Brahmaputra, this type of distribution is attributed largely to the effects of flood events that cause sediment erosion and downvalley reworking. Remobilization and displacement of sediment from fluvial headwaters toward the coast usually does not occur as a single event during a high-flow episode. Rather, the transport process usually occurs episodically, with relatively long periods of temporary sediment storage (residence time) along the fluvial dispersal path (cf. Meade, 1988). This episodic displacement downriver of reworked sediment results in anomalously old dates, i.e. where important proportions of old carbon formed upvalley is incorporated in more recently accreted deposits on the lower fluvial and delta plains (Stanley and Chen, 2000; Stanley and Haït, 2000).

This old-carbon contamination phenomenon most likely prevails on deltaic plain surfaces that accrete sediment rapidly from overbank flood deposition, such as on low-relief coastal sectors of deltas. The easily flooded lower Mississippi and Ganges-Brahmaputra deltaic plains are examples. In the case of the Rhône plain, radiocarbon dating results support the proposition that newly accreted sediment from recent Rhône floods and from alluvial flow along the delta margin incorporates old carbon. It is not surprising that the Rhône plain surfaces currently most susceptible to rapid accumulation of reworked sediment are those likely to incorporate old carbon and record older, pre-modern Holocene ages. The four older dates in this study were from surficial samples recovered in settings proximal to Grand Rhône banks (sites 1, 3) and along margins of the delta (sites 2, 12). These locations are among the deltaic plain sectors to which flood waters continue to have access (van Straaten, 1959).

In contrast to the above, most dates (14 of the 18) from the surface of the Rhône deltaic plain record a modern age (i.e. from as far back as the 17th century AD to the present). This
young-age pattern is attributed to the nature of anthropogenic modification of the deltaic plain, a feature that began to form ~7200 years BP (STRABO; L’HOMER et al. 1981) and has been occupied by humans since at least Hellenistic and Roman times (PASQUALINI and LANDURE, 1995; JORDA and PROVANSAI, 1996). Serious efforts to control the river environment (flood protection, water diversion) were already set in place by the 12th century and continued to intensify to the present (CORRE, 1992). By the early 19th century, most of the original delta plain surface had been artificially modified (LYELL, 1830–1833; L’HOMER, 1992; RODITIS and PONT, 1993): Rhône waters upriver from the delta were dammed and diverted; embankments were emplaced along the two active channel distributaries (Grand and Petit Rhône) that extend to the coast; numerous dikes and water diversion channels were built across much of the plain; and a sea wall diminished flooding along the coast. Large sectors are now converted for agricultural land use (rice cultivation, livestock grazing), evaporite pans for commercial salt works, nature reserves, hunting and tourism. Construction of diverse water control structures and impoundment by an extensive system of dikes and levees now artificially protect large tracts of the deltaic plain from the direct effects of Rhône river flooding. Consequently, much of the deltaic surface subject to cumulative effects of earlier anthropogenic changes is receiving diminished direct water flow, sediment and old carbon from the present Rhône watershed (DIETRICH and MEDICI, 1996).

There are various indications that artificially reduced accretion rates on the deltaic plain have long prevailed. Indirect evidence includes the high proportions of atmospherically-derived relative to riverine (flood) transported pollen in surficial sediment (CAMBON et al., 1997), and the presence of a relatively thin late-Holocene sedimentary cover on archaeological remains and sites (Figure 1), even the older Neolithic site localities (L’HOMER et al., 1981; PASQUALINI and LANDURE, 1995). More direct evidence of marked curtailment of the sediment accumulation is indicated by diminished accretion rates measured in impounded areas (HENSEL et al., 1999). The dating results presented here show that Rhône surface soil layers dated as modern are protected by levees and dikes, areas that have remained relatively isolated for a considerable time from direct effects of river flooding. The modern age of these surficial sediments is attributable to active incorporation of modern atmospherically-equilibrated organic matter from in situ plant growth through bioturbation and the like.

The findings above indicate that in contained Rhône areas, modern radiocarbon dates can complement results of other dating methods (amino acid racemization and others) and archaeological identification of key surficial horizons (cf. PROVANSAI, 1991; JORDA and PROVANSAI, 1996; MORHANGE et al., 1998). Large areas of the Rhône deltaic plain are now at risk due to lowered land elevations resulting from decreased sediment accretion, contemporaneous sediment compaction and land subsidence (GENSOUS and TESSON, 1996; SUANEZ et al., 1997; VELLA et al., 1998). As a consequence, substantial areas of lower-lying deltaic plain are increasingly vulnerable to flooding, storm surges and even a modest relative rise of sea level (PETIT-MAIRE and MARCHAND, 1991; HENSEL et al., 1999). Greater soil saturation and landward incursion of seawater from the Mediterranean margin constitute additional risks suffered by low-lying plain surfaces in areas that do not keep pace with land-sea level fluctuations. Reliable dating of deltaic plain surfaces thus remains one of the more critical steps needed to help plan realistic protection measures for lower-lying sectors of the Rhône delta.

CONCLUSIONS

Most radiocarbon-dated samples from artificially contained surfaces of the Rhône deltaic plain are of modern age, defined here as up to three hundred years ago. It is proposed here that modern radiocarbon dates prevail at diked Rhône delta localities where (1) soil layers form on plain surfaces that are not now periodically buried by flood deposits, and (2) accretion rates of recently deposited sediment incorporating worked old carbon are minimal. This finding contrasts with ages of sediment surfaces of various world deltaic plains that are commonly radiocarbon dated to over 2000 years BP. In the present investigation, surficial sediments that record anomalously old dates occur preferentially on those Rhône plain surfaces where old carbon has accumulated. This old carbon is an important component of eroded fluvial valley sediment that has been recently redeposited at the sample site.

Modern dates at the plain surface of the Rhône system (plant versus organic carbon in sediment) provide reliable chrono-stratigraphic markers against which Holocene dates from subsurface strata can be compared and spurious dates eliminated. Modern radiocarbon dates at many surfaces of the Rhône plain also provide an additional means with which to measure recent motion of land surfaces relative to sea level. Further testing of the above findings and identification of contamination by bioturbation (roots, reworking by organisms) require additional dating of several sub-sample splits from a single surficial sample. Use of both radiocarbon and other dating methods on different cuts of the same sample (organic carbon, plant matter and other) would provide a direct comparison of respective dating methods.

ACKNOWLEDGEMENTS

I thank Mr. V. Bostan for participating in the fieldwork, Mr. T. Jorstad for sedimentologic analyses at the Smithsonian-NMNH Sedimentology Laboratory, and Mr. N. Gipson for technical assistance with manuscript preparation. Reviews of the manuscript by Dr. C. Caran and Messrs. D.G. Hood and T. Jorstad were most helpful. Financial support to initiate this Rhône delta study, part of the Deltas-Global Change Program, was provided by the Smithsonian’s NMNH-Paleobiology Walcott Fund and a grant from the National Geographic Society.

LITERATURE CITED


ARNAUD-FASSETTA, G. and PROVANSAI, M., 1993. Etude géomorph-


