Journal of Coastal Research	16	4	1157–1161	West Palm Beach, Florida	Fall 2000

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

STANLEY, D.J., 2000. Radiocarbon Dating the Artificially Contained Surfaces of the Rhône Deltaic Plain, Southern France. *Journal of Coastal Research,* 16(4), 1157–1161. West Palm Beach (Florida), ISSN 0749-0208.

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 km^2 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; Aloïsi *et al.,* 1978; Leveau and Provansal, 1991; Gensous and Tesson, 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 0–10cm 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

00034 received and accepted in revision 12 March 2000.

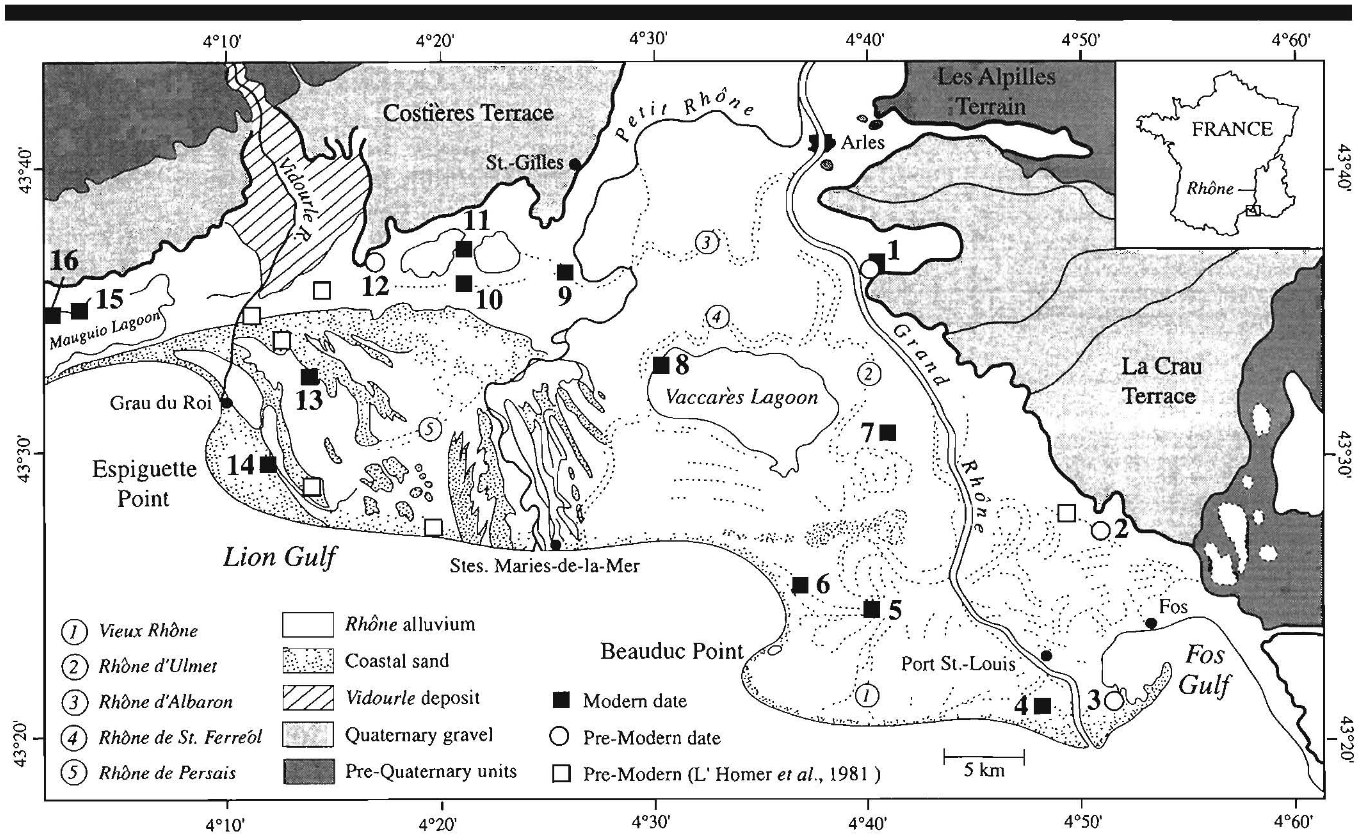

Figure 1. Map showing Rhône deltaic plain, former distributary branches of the Rhône (modified after CORRE, 1992; L'HOMER, 1992), and position of radiocarbon-dated surficial samples (modern and pre-modern ages) at the 16 sites discussed in this study. Localities of Holocene archaeological sites, some Neolithic, at and near the deltaic plain surface, are after L'HOMER *et al.* (1981).

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), $^{13}C/^{12}C$ 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 130 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 $^{13}C/^{12}C$ 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 ~53% (average ~25%). These samples, that include large proportions of both sapric (*i.e.* humus, including fine-grained particulate and dissolved organic mat-

Table 1. *Sedimentologic and radiocarbon data for 18 surficial sediment samples from 16 sites on the Rhône delta. All dates obtained by conventional ^{14}C analysis (Beta Analytic, Miami) except for two sample fractions from site 9 obtained by AMS analysis (NOSAMS, Woods Hole).*

Rhône Sample site	Rhône Field No.	Mean Size (μm)	Total Organic Carbon (%)	Radiocarbon Analysis (Laboratory Number)	Measured Radiocarbon Age (in years BP)	$^{13}C/^{12}C$ Ratio	Conventional Radiocarbon Age (in years BP)
1	99-215	57.4	7.64	Beta-135183	4420 ± 50BP	−26.1‰	4400 ± 50BP
1*	99-215	57.4	7.64	Beta-136892	110.2 ± 1.1%(pmc)	−29.7‰	111.2 ± 1.1%(pmc)
2	99-205	**	**	Beta-135182	1680 ± 40BP	−27.8‰	1640 ± 40BP
3	99-201	63.2	18.71	Beta-135181	1550 ± 70BP	−20.9‰	1620 ± 70BP
4	99-224	90.4	11.85	Beta-135184	101.0 ± 0.8%(pmc)	−25.6‰	101.1 ± 0.8%(pmc)
5	99-228	169.5	25.86	Beta-135185	105.6 ± 0.7%(pmc)	−26.5‰	105.9 ± 0.7%(pmc)
6	99-235	116.0	37.42	Beta-135186	104.1 ± 0.7%(pmc)	−15.8‰	102.2 ± 0.7%(pmc)
7	99-238	194.7	20.82	Beta-135187	112.8 ± 0.5%(pmc)	−28.4‰	113.6 ± 0.5%(pmc)
8	99-273	89.4	21.82	Beta-135188	120.7 ± 0.8%(pmc)	−25.0‰	120.7 ± 0.8%(pmc)
9	99-258	35.8	10.65	OS-22460	**	−25.9‰	103.3 ± 0.6%(pmc)
9*	99-258	35.8	10.65	OS-22702	**	−25.9‰	114.0 ± 0.5%(pmc)
10	99-322	163.7	39.32	Beta-135195	113.6 ± 0.8%(pmc)	−26.5‰	113.9 ± 0.8%(pmc)
11	99-323	117.3	57.85	Beta-135196	125.7 ± 1.0%(pmc)	−26.3‰	126.0 ± 1.0%(pmc)
12	99-313	36.5	18.40	Beta-135194	860 ± 60BP	−26.0‰	840 ± 60BP
13	99-296	92.3	24.36	Beta-135193	112.4 ± 0.8%(pmc)	−25.7‰	112.6 ± 0.8%(pmc)
14	99-293	122.5	6.77	Beta-135191	102.5 ± 1.0%(pmc)	−20.1‰	101.5 ± 1.0%(pmc)
15	99-285	111.4	37.24	Beta-135189	114.7 ± 0.7%(pmc)	−24.7‰	114.7 ± 0.7%(pmc)
16	99-286	**	**	Beta-135190	116.1 ± 0.5%(pmc)	−28.8‰	117.0 ± 0.5%(pmc)

Notes: Dates are obtained from organic sediment (acid washes), except samples 1* and 9* using plant fragments and fibrous floral material (acid/alkali/acid). Dates are reported as years before present (1950 AD) and not calibrated; quoted errors represent 1 standard deviation statistics.
** = data not available.
(pmc) = percent modern carbon.

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 Meyrranne. Two other samples were also collected east of the Grand Rhône, one at site 3 near its mouth at They de Roustan (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 63μm (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 recorded 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 HAIT, 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 PROVANSAL, 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 preserves, hunting and tourism. Construction of diverse water control structures and impoundment by an extensive system of dikes and levees now artifically 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 (DIETRICHT 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.* PROVANSAL, 1991; JORDA and PROVANSAL, 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 reworked 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

ALOÏSI, J.-C.; MONACO, A.; PLANCHAIS, N; THOMMERET, J., and THOMMERET, Y., 1978. The Holocene transgression in the Golfe du Lion, southwestern France: paleogeographic and paleobotanical evolution. *Géographie physique, Quaternaire,* 32(2), 145–162.

ARNAUD-FASSETTA, G. and PROVANSAL, M., 1993. Etude géomorphique du delta du Rhône: l'évolution des milieux de sédimentation fluviatiles au cours de l'Holocène récent. *Méditerranée,* 3.4, 31–42.

BANERJEE, M. and SEN, P., 1987. Paleobiology in understanding the change of sea level and coast line in Bengal Basin during Holocene period. *Indian Journal of Earth Sciences,* 14, 307–320.

CAMBON, G.; SUC, J.-P.; ALOISI, P.G.; MONACO, A.; TOUZANI, A.; DUZER, D., and FERRIER, J., 1997. Modern pollen deposition in the Rhône delta area (lagoonal and marine sediments), France. *Grana,* 36, 105–113.

CORRE, J.-J., 1992. Implications of climatic changes on the Golfe du Lion. *In:* JEFTIC, L.; MILLIMAN, J.D., and SESTINI, G. (eds.), *Climatic Change and the Mediterranean.* London: Edward Arnold, 328–427.

DIETRICHT, D. and MEDICI, F., 1996. Artificial radionuclides in the sediments of the Rhône river: a snapshot of the situation during winter 1994/95. *Terra Nova,* 8, 430–434.

GENSOUS, B. and TESSON, M., 1996. Sequence stratigraphy, seismic profiles, and cores of Pleistocene deposits on the Rhône continental shelf. *Sedimentary Geology,* 105, 183–190.

HENSEL, P.F.; DAY, J.W., and PONT, D., 1999. Wetland vertical accretion and soil elevation change in the Rhône River delta, France: The importance of riverine flooding. *Journal of Coastal Research,* 15, 668–681.

JORDA, M. and PROVANSAL, M., 1996. Impact de l'anthropisation et du climat sur le détrisme en France du sud-est (Alpes du sud et Provence). *Bulletin de la Société Géologique de France,* 1, 160–168.

LEVEAU, P. and PROVANSAL, M., 1991. Construction deltaïque et histoire des systèmes agricoles, le cas d'un petit delta: l'Arc, étang de Berre. *Revue Archéologique Narbonnaise,* 23, 111–131.

L'HOMER, A., 1992. Sea-level changes and impacts on the Rhône delta coastal lowlands. *In:* TOOLEY, M.J. and JELGERSMA, S. (eds.), *Impacts of Sea-level Rise on European Coastal Lowlands.* Oxford, UK: Oxford University Press, 136–152.

L'HOMER, A.; BAZILE, F., and THOMMERET, Y., 1981. Principales étapes de l'édification du delta du Rhône de 7 000 BP à nos jours; Variations du niveau marin. *Oceanis,* 7, 389–408.

LYELL, C., 1830–1833. *Principles of Geology.* Vol. 1, Chapter 13. London: Murray, 220–239.

MCFARLAN, E., 1961. Radiocarbon dating of Late Quaternary deposits, south Louisiana. *Geological Society of America Bulletin,* 72, 129–158.

MEADE, R., 1988. Movement and storage of sediment in river systems. *In:* LERMAN, A. and MEYBECK, M., (eds.), *Physical and Chemical Weathering in Geochemical Cycle.* Dordrecht, The Netherlands: Kluwer Academic Publishers, 165–179.

MORHANGE, C.; PROVANSAL, M.; VELLA, C.; ARNAUD, P.; BOURCIER, M., and LABOREL, J., 1998. Montée relative du niveau de la mer et mouvements du sol à l'Holocène en basse Provence (France, Méditerranée). *Annales de Géographie,* 600, 139–159.

OOMKENS, E., 1970. Depositional sequences and sand distribution in the postglacial Rhône delta complex. *In:* MORGAN, J.P. (ed.), *Deltaic Sedimentation Modern and Ancient.* SEPM Special Publication, 15, 198–212.

PASQUALINI, M. and LANDURE, C., 1995. *Delta du Rhône Programme de Recherche.* Service Régional de l'Archéologie de Provence-Alpes-Côte d'Azur, Direction Régionale des Affaires Culturelles, 246p.

PETIT-MAIRE, N. and MARCHAND, J., 1991. La Camargue au XXIe siècle. *La Recherche,* 234, 976–978.

PROVANSAL, M., 1991. Variations verticales du trait de côtes en Provence depuis 5000 ans. *Méditerranée,* 4, 15–22.

RAPPORT CAMARGUE, 1970. *D.D.A. et C.N.A. du Bas-Rhône et du Languedoc, Arles.*

RODITIS, J.-C. and PONT, D., 1993. Dynamique fluviale et milieux de sédimentation du Rhône à l'amont immédiat de son delta. *Méditerranée,* 78, 5–18.

STANLEY, D.; MCREA, J., and WALDRON, J., 1996. *Nile delta drill core and sample database for 1985–1994: Mediterranean Basin (MEDIBA) Program.* Smithsonian Contributions to the Marine Sciences, 37. Washington, D.C.: Smithsonian Institution Press, 428p.

STANLEY, D. and CHEN, Z., 2000. Radiocarbon dates in China's Holocene Yangtze delta: record of sediment storage and reworking, not timing of deposition. *Journal of Coastal Research,* 16, (in press).

STANLEY, D. and HAIT, A., 2000. Deltas, radiocarbon dating, and measurements of sediment storage and subsidence. *Geology,* 28, 295–298.

STRABO. *The Geography of Strabo, Book IV* (English translation, H.L. JONES, 1917). London: William Heinemann Ltd., 163–295.

STUIVER, M. and POLACH, H., 1977. Reporting of ^{14}C data. *Radiocarbon,* 19, 355–363.

SUANEZ, S.; PROSPER-LAGET, V., and PROVANSAL, M, 1997. Variations rélatives du niveau marin dans le delta du Rhône et à Marseille. *Comptes Rendus de l'Académie des Science, Paris,* 324, 639–646.

TÖRNQVIST, T.E.; VAN REE, M.H.M.; VAN'T VEER, R., and VAN GEEL, B., 1998. Improving methodology for high-resolution reconstruction of sea-level rise and neotectonics by paleoecological analysis and AMS ^{14}C dating of basal peats. *Quaternary Research,* 49, 72–85.

VAN STRAATEN, L.M.J.U., 1959. Littoral and submarine morphology of the Rhône delta. *In:* RUSSELL, R.J. (ed.), *Second Coastal Geography Conference,* Washington D.C.: Geography Branch, Office of Naval Research, 233–264.

VELLA, C.; BOURCIER, M., and PROVANSAL, M., 1998. Montée du niveau marin et sédimentation holocène sur la marge orientale du delta du Rhône, Provence, France. *Bulletin de la Société Géologique de France,* 169, 403–414.

YAN, Q. and XU, S., 1987. *Recent Yangtze delta deposits.* Shanghai: East China Normal University Press, 438p.