on an electron-transparent, free-standing SiO\textsubscript{2} film supported on a GaAs wafer (15). A 2.2-nm-long aryl di-isonitrile

\[
\begin{array}{c}
\text{Et} \quad \text{Et} \\
\text{C} = \text{N} \quad \text{C} \quad = \quad \text{N} \\
\text{C} = \text{N} \quad \text{C}
\end{array}
\]

was used to link the clusters. The measured room-temperature conductance of the unlinked array was 133 nS and of the linked network was 78 nS. After a TEM image of the LCN was obtained, the backside of the substrate was metallized and the current-voltage relationship of the LCN was measured as a function of temperature T (Fig. 5).

The low-bias conductance (Fig. 5) exhibits Coulomb charging behavior and followed the relation

\[
G_{\text{C}} = G_{\text{e}} e^{-E_{\text{A}}/k_{\text{B}} T}
\]

where \(G_{\text{e}}\) is the conductance as \(T \to \infty\), \(E_{\text{A}}\) is an activation energy, and \(k_{\text{B}}\) is Boltzmann’s constant. The best fit parameters to these data are \(G_{\text{e}} = 1.12 \times 10^{-16}\text{S}\) and \(E_{\text{A}} = 97\text{meV}\). The capacitance of a cluster embedded in this LCN (cluster diameter of 3.7 nm, and a gap of 1.9 nm, as estimated by TEM) was calculated with the FASTCAP program (16) and used to estimate the Coulomb charging energy, which should correspond to \(E_{\text{A}}\) for the array. This calculation yields a value of 200 meV/\(e_{\text{a}}\), for \(E_{\text{A}} (e_{\text{a}}\), the relative dielectric constant of the organic molecules, is estimated to be 1.5 to 2). The agreement with the experimental activation energy, \(E_{\text{A}} = 97\text{meV}\), is quite good. The dot-to-dot resistance of this LCN is \(R_{\text{D}} \sim (G_{\text{e}})^{-1} = 0.9\text{megohm}\). We estimate the maximum number of molecules linking adjacent clusters to be 32, which would yield an estimated resistance of 29 megohms per molecule. The resistance of a single 22ADI molecule is predicted to be 43 megohms from a semiempirical treatment of a molecule bridging the gap between two gold surfaces by using an extended Hückel method (17). The close agreement between these two estimates of molecular resistance indicates that the assumption that the clusters are linked by 22ADI is reasonable.

A general synthesis strategy for fabrication of a 2D network of metal clusters linked by organic molecules has been outlined. The power of this strategy resides in its inherent flexibility. By altering the size or composition of the clusters, the length and chemical structure of the organic molecules used as molecular interconnects, and the characteristics of the substrate, a wide range of electronic behavior can be achieved. Coulomb charging behavior has been observed in such a linked cluster network.

REFERENCES AND NOTES


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A Revised Chronology for Mississippi River Subdelta

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Radiocarbon measurements by accelerator mass spectrometry relating to three of the four late Holocene Mississippi River subdelta yielded consistent results and were found to differ by up to 2000 carbon-14 years from previously inferred ages. These geological data are in agreement with archaeological carbon-14 data and stratigraphic ages based on ceramic seriation and were used to develop a revised chronological framework, which has implications for prehistoric human settlement patterns, coastal evolution and wetland loss, and sequence-stratigraphic interpretations.

The geochronology of the Mississippi delta is relevant to investigations of fluvial development in relation to deltaic evolution (1, 2), coastal evolution (3), archaeological research (4, 5), coastal wetland loss (6), and sequence-stratigraphic interpretations (7). For example, the age of subdelta (8) is an important input parameter for simulation models of wetland loss, a severe environmental problem in this region. The chronology of Mississippi River subdelta is a well-known textbook example of clastic sedimentology (9), and it can contribute to computer simulations of alluvial architecture (10) where avulsion (channel diversion) is a crucial component. Early stratigraphic studies of Holocene sediments in this region (Fig. 1) revealed a relative chronology that is still largely valid (11). The first 14C ages were published in the early 1950s (12), and subsequent investigations (13, 14) contributed to the development of a numerical-age chronology for Mississippi River subdelta, which was later revised toward older ages by Frazier (15). His chronology has since been used for most Mississippi delta studies (1-7). However, some concerns can be raised about Frazier’s sampling strategy. Many of his samples cover

SCIENCE • VOL. 273 • 20 SEPTEMBER 1996

1693
large vertical intervals (usually close to 0.5 m) and their association with events of interest is not always clear (16). Modifications of Frazier's chronology have included a shift of the beginning of activity of the Lafourche subdelta (Fig. 1) from 3500 to 2500 years before present (B.P.) (17), whereas other revisions (18) shifted delta-llobe ages further back in time. Such amendments underline the present uncertainties in subdelta ages. Recent archaeological studies showed that Frazier's chronology is inconsistent with data from Native American sites (16, 19). The St. Bernard and Lafourche subdeltas revealed surprisingly young $^{14}$C ages for their inhabitation compared with assumed ages of the beginning of fluvial activity of 4600 and 3500 years B.P., respectively (20).

To address these age discrepancies, we used a different sampling strategy (21, 22) in the Mississippi delta downstream of Donaldsonville, Louisiana (Fig. 1), where the trunk segments of the Plaquemines-Modern, Lafourche, and St. Bernard subdeltas are located. We focused on dating the beginning of subdelta activity by sampling the top of peat beds underneath clayey overbank deposits (23). The $^{14}$C ages from the top of organic beds underneath overbank deposits (sample type 1) yield ages for the beginning of fluvial activity, whereas ages from the base of organic beds overlying overbank deposits (sample type 2) and ages from the base of organic residual-channel fills (sample type 3) represent the end of activity (Fig. 2). Type 1 samples provide the most consistent results (22). We constructed cross sections (Figs. 3 and 4) to optimize the selection of sampling sites. Other sampling sites are presented as individual cores (Fig. 5).

The cross section at Paincourtville (Fig. 3) shows part of the Bayou Lafourche channel belt and its genetically associated overbank deposits. A lateral facies change in thickness and grain size occurs away from the channel belt. A laterally continuous peat bed underlying these strata covers the narrow channel belt and fine-grained overbank deposits of a buried distributary. Presently, we lack the data to provide a definitive stratigraphic correlation and therefore refer to it as a pre-St. Bernard distributary. We $^{14}$C dated the onset of activity of the Lafourche subdelta at three locations (eight measurements) and obtained consistent results (Table 1 and Fig. 3), with ages clustering around 1500 years B.P. Additional samples from the middle and basal part of the peat bed (Fig. 3) indicate that organic accumulation spanned at least 3400 $^{14}$C years. We consider the basal age of $\sim$4900 years B.P. a minimum age for the pre-St. Bernard distributary.

A cross section near Vacherie (Fig. 4) shows part of a channel belt of the Plaquemines-Modern subdelta, the St. Bernard subdelta, or possibly both. The related overbank deposits consist of two stacked units, as indicated by oxidized and consolidated sediments buried by a younger bed. We interpret these strata as belonging to the St.

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**Fig. 1.** Outline of the Mississippi River subdeltas [modified from (75)], surface geology of the study area (1), and the location of cross sections and $^{14}$C-dated cores.

**Fig. 2.** Sampling strategy for dating the period of activity of distributaries (22). Circles with numbers refer to $^{14}$C sample types.

**Fig. 3 (left).** Cross section of deposits at Paincourtville. The $^{14}$C ages are weighted means for multiple samples, MSL, mean sea level.

**Fig. 4 (above).** Cross section of deposits at Vacherie. Same color legend as in Fig. 3.
and the Plaquemines-Modern sub-deltas, respectively. This confirms previous inferences (14, 24, 25) that this reach of the Mississippi River was occupied during St. Bernard time and subsequently reactivated (26). Carbon-14 ages from the top of the underlying peat bed (Fig. 4), and at two sites north of the river (Fig. 5, Convent I and Lutcher I) indicate an age of ~3600 years B.P. (four measurements). A thinner overbank deposit underlies this organic bed and presumably belongs to another pre-St. Bernard distributary. A thin peat bed locally separates the overbank deposits of the St. Bernard and Plaquemines-Modern sub-deltas. The top of this bed provided 14C ages of 1200 to 1400 years B.P. (Fig. 5, Lagan I), similar to an earlier measurement (1325 ± 105 years B.P.) of an identical transition in the same area (24).

The distribution of dated archaeological sites in the eastern Mississippi delta (27) is shown in Fig. 6. The oldest human occupation was attributed to the Late Archaic period and is in the upstream part of the St. Bernard subdelta (28). Archaeologically derived 14C data and stratigraphic ages based on ceramic seriation indicate that sites become progressively younger eastward (29-31), with initial occupation of the easternmost St. Bernard subdelta occurring during the Marksville period (5, 29). The earliest inhabitation of the Lafourche subdelta dates to the very end of the Baytown period (32), whereas inhabitation of sites near the mouth of Bayou Lafourche dates to the end of the Coles Creek period. The earliest 14C age for human settlement in this area is 980 ± 60 years B.P. (33). Initial occupation of the Plaquemines-Modern subdelta occurred during the late Baytown or early Coles Creek period. A buried site along a crevasse channel southwest of New Orleans has a 14C age for initial occupation of 1350 ± 60 years B.P. (30).

The 14C measurements for the beginning of activity of the St. Bernard, Lafourche, and Plaquemines-Modern sub-deltas yield weighted mean ages of 3569 ± 24, 1491 ± 13, and 1322 ± 22 years B.P., respectively, and provide maximum ages for all downstream distributaries belonging to these sub-deltas. Calibration to calendar years (34) yields 95% confidence age ranges of 1960 to 1832 B.C. (St. Bernard), 566 to 608 A.D. (Lafourche), and 664 to 744 A.D. (Plaquemines-Modern), in agreement with existing archaeological data. The delta lobes evidently were rapidly occupied after their formation (33, 35). Apparently the formation of the Lafourche and Plaquemines-Modern sub-deltas started almost simultaneously. Similar phenomena have been observed in the Rhine-Meuse delta, The Netherlands (36).

Our results show that the chronology of Mississippi River sub-deltas needs reevaluation. When our data are compared with previous chronological work (Table 2), McFarlan's (14) and Saucier's (24) results are more consistent with our findings than those of Frazier (15). This is not surprising, because these earlier chronologies were based on 14C ages of organic materials under future natural levees. We believe that our results constitute an initial framework for a revised 14C chronology for the Mississippi delta.

Table 1. List of 14C ages. The UMC number is the laboratory number. UTM, universal transverse mercator.

<table>
<thead>
<tr>
<th>UMC number</th>
<th>14C age (years B.P.)</th>
<th>3145 (per mil)</th>
<th>UTM coordinates and surface elevation above mean sea level (m)</th>
<th>Depth below surface (cm)</th>
<th>Sample name</th>
<th>Material¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>3871</td>
<td>1469 ± 35</td>
<td>-27.0</td>
<td>3319.240N, 686.920E, 4.7</td>
<td>891–893</td>
<td>P-I-1a</td>
<td>1 Tdt</td>
</tr>
<tr>
<td>3872</td>
<td>1486 ± 55</td>
<td>-25.0</td>
<td>3319.240N, 686.920E, 4.7</td>
<td>891–893</td>
<td>P-I-1b</td>
<td>1 Tdc</td>
</tr>
<tr>
<td>3873</td>
<td>3780 ± 59</td>
<td>-27.7</td>
<td>3319.240N, 686.920E, 4.7</td>
<td>1045–1047</td>
<td>P-I-2</td>
<td>10 Sr</td>
</tr>
<tr>
<td>3874</td>
<td>4869 ± 56</td>
<td>-28.4</td>
<td>3318.560N, 685.700E, 3.5</td>
<td>1125–1128</td>
<td>P-I-3</td>
<td>5 Cs</td>
</tr>
<tr>
<td>3875</td>
<td>1483 ± 26</td>
<td>-25.6</td>
<td>3318.560N, 685.700E, 3.5</td>
<td>530–532</td>
<td>P-II-1a</td>
<td>1 Tdt</td>
</tr>
<tr>
<td>3876</td>
<td>1578 ± 37</td>
<td>-23.5</td>
<td>3317.660N, 683.820E, 1.0</td>
<td>530–532</td>
<td>P-II-1b</td>
<td>1 Tdc</td>
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<tr>
<td>3877</td>
<td>1503 ± 31</td>
<td>-26.8</td>
<td>3317.660N, 683.820E, 1.0</td>
<td>216–220</td>
<td>P-III-1a</td>
<td>1 Tdt</td>
</tr>
<tr>
<td>3878</td>
<td>1462 ± 33</td>
<td>-24.5</td>
<td>3317.660N, 683.820E, 1.0</td>
<td>216–220</td>
<td>P-III-1b</td>
<td>1 Tdt</td>
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<tr>
<td>3879</td>
<td>1438 ± 37</td>
<td>-24.7</td>
<td>3317.660N, 683.820E, 1.0</td>
<td>216–220</td>
<td>P-III-1c</td>
<td>1 Tdc</td>
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<tr>
<td>3880</td>
<td>1524 ± 23</td>
<td>-25.1</td>
<td>3317.660N, 683.820E, 1.0</td>
<td>216–220</td>
<td>P-III-1d</td>
<td>1 Tdc</td>
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<tr>
<td>3881</td>
<td>3532 ± 38</td>
<td>-27.4</td>
<td>3326.940N, 720.500E, 1.8</td>
<td>468–470</td>
<td>L-I-1a</td>
<td>1 Ch</td>
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<tr>
<td>3882</td>
<td>3864 ± 73</td>
<td>-23.5</td>
<td>3326.940N, 720.500E, 1.8</td>
<td>468–470</td>
<td>L-I-1b</td>
<td>1 Ch</td>
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<td>3883</td>
<td>4917 ± 57</td>
<td>-27.9</td>
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<td>672–675</td>
<td>L-I-2</td>
<td>7 Sr</td>
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<td>3884</td>
<td>3541 ± 46</td>
<td>-28.3</td>
<td>3322.840N, 711.960E, 3.3</td>
<td>552–554</td>
<td>C-I-1</td>
<td>8 Sr</td>
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<tr>
<td>3885</td>
<td>3631 ± 48</td>
<td>-27.4</td>
<td>3317.720N, 716.720E, 2.8</td>
<td>608–610</td>
<td>V-I-1</td>
<td>8 Sr</td>
</tr>
<tr>
<td>4456</td>
<td>1400 ± 60</td>
<td>-24.9</td>
<td>3316.380N, 712.360E, 1.9</td>
<td>157–159</td>
<td>La-I-1a</td>
<td>1 Tdc</td>
</tr>
<tr>
<td>4457</td>
<td>1380 ± 31</td>
<td>-25.8</td>
<td>3316.380N, 712.360E, 1.9</td>
<td>157–159</td>
<td>La-I-1b</td>
<td>6 Ch</td>
</tr>
<tr>
<td>4458</td>
<td>1197 ± 39</td>
<td>-32.0</td>
<td>3316.380N, 712.360E, 1.9</td>
<td>157–159</td>
<td>La-I-1c</td>
<td>11 U</td>
</tr>
</tbody>
</table>

¹P, Pannouville; L, Lutcher; C, Convent; V, Vacherie; and L, Lagan. Tdt (or Tdc), Taxodium distichum twig (cone); Sr, Scorpus cf. robustus nut; Cs, Carex sp. nut; Ch, charcoal fragment; and U, unidentified nut.

Table 2. Beginning of activity of Mississippi River sub-deltas according to various authors [McFarlan (14), Frazier (15), and Saucier (24)]. SB, St. Bernard; LF, Lafourche; and PM, Plaquemines-Modern.

<table>
<thead>
<tr>
<th>Author</th>
<th>Beginning of activity for subdelta (14C years B.P.)</th>
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<tr>
<td>McFarlan</td>
<td>SB 2750–2200 ~1500 ~1200</td>
</tr>
<tr>
<td>Frazier</td>
<td>LF -3600 –3600 ~1200 ~1000</td>
</tr>
<tr>
<td>Saucier</td>
<td>PM ~4000 ~4000 ~1200 ~1200</td>
</tr>
<tr>
<td>This study</td>
<td>3569 ± 24 1491 ± 13 1322 ± 22</td>
</tr>
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</table>

Fig. 5. Cores Lagan I, Convent I, and Lutcher I. Same color legend as in Fig. 3. The 14C ages are weighted means for multiple samples.

Fig. 6. The distribution and age of archaeological sites in the eastern Mississippi delta (27).
Ribosomes and large RNA components of spliceosomes and ribosomes fold into complex three-dimensional architectures. To form these biologically active structures, helical regions must pack together specifically. Comparative sequence analysis (1, 2), biochemical experiments (2–5), and modeling based on intermolecular contacts in crystals of small RNAs (6) have identified some elements responsible for long-range tertiary interactions in large RNAs, but their molecular details are largely unknown. The crystal structure of the 160-nucleotide P4-P6 domain of the Tetrahymena thermophila self-splicing intron (7) has revealed several new types of long-range contacts, including three examples of the adenosine platform motif described below.

The secondary structure of the P4-P6 domain, like that of many other large RNAs, contains base-paired regions interspersed with internal loops (Fig. 1A). As in other RNAs, many of the loops contain a

**RNA Tertiary Mediation by Adenosine Platforms**

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