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Supplemental file for
Tidal Rhythmites in the Southern Bouse Formation as Evidence for Post-Miocene Uplift of the Lower Colorado River Corridor

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RATIONALE AND METHODS

Tides are effective agents of sediment transport, sorting and deposition. Their effectiveness and resulting sedimentary deposits are directly related to the tidal range and resulting tidal velocity (FitzGerald and Nummedal, 1983; Boothroyd, 1985; Williams, 2000). Tidal successions can be deposited and preserved as either horizontally laminated rhythmites (e.g., Williams, 1989, 2000; Chan et al., 1994; Mueller et al., 2002), laterally accreted foresets (e.g., Visser, 1980; de Boer et al., 1989; Deynoux et al., 1993; Bose et al., 1997; Eriksson and Simpson, 2000, 2004; Mueller et al., 2002; Tape et al., 2003; Mazumder, 2004; Longhitano, 2011), or laterally accreted sigmoidal bundles (e.g., Kreisa and Moila, 1986). With this understanding, the basic data set acquired for tidal rhythmite analysis includes grains size, lithology, and thickness measurements of foreset bedding and laminae, limited to intervals with well-preserved and uninterrupted stratification. The thickness variations of two layers – one thin and one thick – typically alternate between siliciclastic-rich and bioclastic lithologies in the Bouse Formation, similar to other silic-bioclastic tidal rhythmites (e.g., Longhitano, 2011). Two layers comprise one couplet. Layer thicknesses were measured from two horizontal rhythmite successions *(n=164, and n=87)*, one dune foresest succession *(n=78)*, and one sigmoidal bundle succession *(n=36).* The thicknesses of successive rhythmites of alternating lithologies are plotted as a thickness series (in contrast to a true time series), where layer thickness is plotted against rhythmite layer number. Fourier analysis detects the presence of cyclicity in the dataset (Archer, 1994; Archer et al., 1995; Adkins & Eriksson, 1998). Raw data were demeaned and detrended prior to power spectral analysis. Demeaning prepares the data for detrending and removes the infinite-period component of the signal, and detrending minimizes trends of period longer than the data duration (Granger and Joyeux, 1980; Beran, 1994).

Modelling

FFTs

The tidal record shown in Fig. 3A is made using the amplitudes and phases of all major tidal components at San Felipe, in the northern Gulf of California. These are calculated using the amplitudes and frequencies of the 7 dominant tidal components (four semidiurnal and 3 diurnal).

Local basin effects control the amplitude of each of the 7 dominant and many minor solar and lunar tidal components. The major components have frequencies near 1 and 2 cycles per day, with the principal semidiurnal solar component (S2) occurring exactly twice a day. The principal semidiurnal lunar component (M2) occurs with a frequency of 1.932 cycles per day. This is

driven by the P=29.53-day cycle of the Moon's phase changes, which gives a frequency of 2*[(P-1)/P] = 2*[28.53/29.53] = 1.932 cycles per day.

In modeling northern Gulf of California tides, Marinone (1997) finds these can be modeled well using only the S2 and M2 components, and that the amplitude ratio M2/S2 is about 1.65.

Table 1 (from Kvale, 2006)
for San Felipe:

Component	Period	Freq.	Amp*	Cause of component
M2	12.42	1.932	164.5	Principal lunar (semidiurnal)
S2	12.00	2.000	99.2	Principal solar (semidiurnal)
N2	12.66	1.896	42.0	Larger elliptical lunar (semidiurnal)
K2	11.97	2.005	26.4	Combined declinational lunar & declinational solar (semidiurnal)
K1	23.93	1.003	41.6	Combined declinational lunar & declinational solar (diurnal)
O1	25.82	0.930	26.3	Principal lunar (diurnal)
P1	24.07	0.997	13.0	Principal solar (diurnal)

*from Marinone (1997)

Our data are not long enough to resolve the small differences between the individual diurnal peaks. Instead, we use to the average of the three diurnal frequencies, weighted by their amplitudes given in Table 1. This gives Wa1=0.98 cycles per day. A similar calculation for the four semidiurnal frequencies gives Wa2=1.95 cycles per day.

See FFT Matlab Code, below

Least Squares

An FFT calculates the amplitudes of constituent sine and cosine waves that have an integer number of cycles in the analyzed time window. These amplitudes are identical to the amplitudes calculated by least squares fitting of sine and cosine waves. If the energy at frequencies intermediate to integer number of cycles is of interest, sine and cosine waves of these intermediate frequencies can be found with least squares fitting. Our results of this analysis are shown in Fig. 1 Supplement. In the right-hand column of this figure we show an enlargement of these results at the low-frequency end of the spectrum, where there are relatively few amplitude estimates obtained from the FFT.

***Fig. 1 Supplement**: FFT and Least Squares comparison*

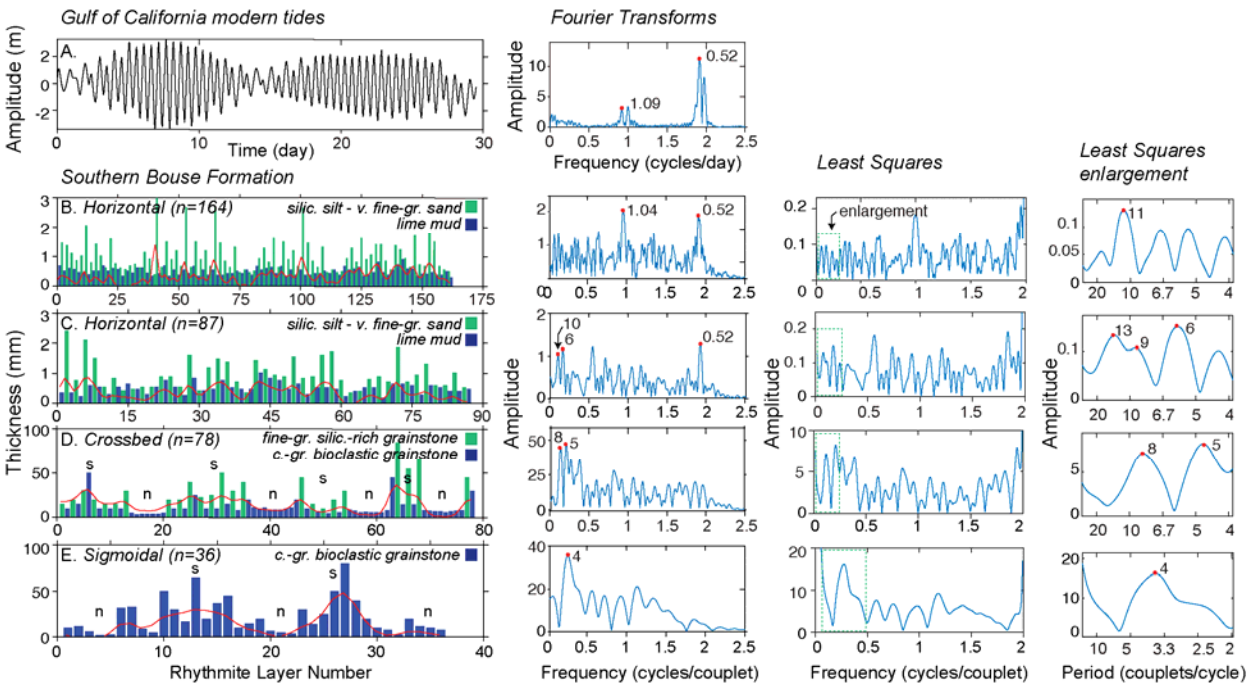

Fig. 1 Supplement: FFT & Least Squares comparison. Green boxes around Least Squares column indicate enlargement under Lease Squares Enlargement column. Red dots with numbers indicate the period (1/frequency).

See Least Squares Matlab code, below

Fig. 2 Photo Locations

Photo	**Latitude**	**Longitude**
2B	33.2893	-114.6323
2C	33.2515	-114.7792
2D	33.3562	-114.7248
2E	33.2698	-114.6421
Thalassinoides	33.2574	-114.6416

wavy, flaser, lenticular bedding	33.2696	-114.6411
horizontal thin-thick couplets	33.2633	-114.6360

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MATLAB CODE – FFT

```
% Matlab Code Supplement - FFT
% for 'Tidal rhythmites in the Southern Bouse Formation as evidence for Post-
Miocene uplift of the lower Colorado River corridor'
% Brennan O'Connell, Rebecca J. Dorsey, and Eugene D. Humphreys
% Department of Earth Sciences, University of Oregon, Eugene, Oregon 97403,
USA

%-------------------------------------------------------------------------
%-------------------------------------------------------------------------
%-------------------------------------------------------------------------

% load tide data from actual north-Gulf of California site (Tides.in)
% Figure 3A
% Tides.in  = one month of modern tide record at San Felipe, Gulf of
% California (http://sanfelipe.com.mx/weather/tide-calendars)

clear all
figure(1), clf

load Tides.in     % N. GoC tide for 31 days, picked at peaks & troughs
n= size(Tides,1);
T= Tides(:,1);    %  Time
H= Tides(:,2);    %  Hight
tlim= 31;         %  in days (truncated to 29.5 days below)

%%%%%%%  truncate to 29.5 days %%%%%
n= round(n*(29.5/31));   tlim= tlim*(29.5/31);
T= T(1:n);   H= H(1:n);

% make one continuous series
  T(107:n)= T(107:n)+(733-36);   H(107:n)= H(107:n)-(702-579);
  T( 79:n)= T( 79:n)+(726-27);   H( 79:n)= H( 79:n)-(559-429);
  T( 52:n)= T( 52:n)+(720-22);   H( 52:n)= H( 52:n)-(463-330);
  T( 25:n)= T( 25:n)+(727-29);   H( 25:n)= H( 25:n)-(283-157);

% Scale input data, using info from digitized plot
  T =  T-T(1);       % first time = 0
  T =  T*(tlim/T(n));% last  time = tlim  [scaling from plot: T=T*(7/698)]
  H = -H*(7/97);     % scale Height to meters
  H =  H-mean(H);    % demean H   [actual low tide = -1.6 m]

% make dense and regularly sampled in time
  factor = 8;  % use integer
  H = interp(H,factor);
    H = H(1:n*factor-(factor-1));  % truncate overshoot
  T = interp(T,factor);
    T = T(1:n*factor-(factor-1));  % truncate overshoot
  [H,T] = resample(H,T);           % make regular time steps
  nt = length(T);
  dT = T(2);                 % time step, in days. T = dT*[0 1 2 3 ...]
  n4 = 4*2^ceil(log2(nt));  % over 4 x nt, for Rhy & zero padding
  tlim4 = tlim*(n4/nt);     % time at end of extended (zero-padded) array
  H =  H-mean(H);           % demeaned again

  %plot Fig.3A time series
  subplot(5,2,1), hold on
```

```
     plot(T,H), axis tight
     xlim([0 30])
     set(gca,'TickDir','out')
     title('Gulf of California modern tides')
     xlabel('Time (day)'), ylabel('Amplitude (m)')
      box on
      axis tight
      hold on

% Fourier Transform tidal record
FH = fft(H,n4)/n4;    % Fourier transform zero-padded time series, scaled
FH = FH*(n4/n);       % scale to compensate for zero padding
                      %        Output of fft is as follows:
                      %  DC is at 0-th point, Nyquest at (nt/2+1)-th point
                      %   D . . . N . . .     (for nt=8)
                      %   0 + + + - - - -     (sign of frequency)
FH = fftshift(FH);    % put negative frequencies on lhs where they belong
                      %  DC is at (nt/2+1)-th point, Nyquest at 0-th point
                      %   N . . . D . . .     (for nt=8)
                      %   - - - - 0 + + +     (sign of frequency)
nf = n4/2;            % number of non-negative frequencies
kf = 1:n4;            % kf is freq kounter:    1  2  3  4  5  6  7  8
freq=(kf-nf-1)/tlim4;% freq is actual freq: (-4 -3 -2 -1  0  1  2  3)/tlim4
                      % freq(DC)=0. Next freq is for 1 cycle. this is dw.
FH2 = 2*FH(nf+1:n4); % from DC to highest non-Nyq. doubled for rhs
freq4=freq(nf+1:n4)';% nf+1 is DC.
  fprintf('%8.5f\n',n4*dT*freq4(2));% if 1, 1st freq is fundamental period

  %Plot FFT
  subplot(5,2,2)
  Pa = 0.01;          % scale the phase plot
  phase = Pa*(180/pi)*atan2(imag(FH2),real(FH2));
  plot([0 29.5], 180*Pa*[1 1],'r--')
  semilogx(freq4,phase,'r')  % phase spectrum
  plot(freq4,abs(FH2))  % amplitude spectrum
  hold off
  axis tight
  hold on
  xlim([0.00 2.5])   % 33 days to 3 cycles/day
  ylim([0.00 14])
  set(gca,'YTick',[0 5 10])
  set(gca,'TickDir','out')
  title('FFT of northern GoC tides')
  xlabel('Frequency (cycles/day)'), ylabel('Amplitude')

[pks, locs]=findpeaks(abs(FH2),freq4,'SortStr','descend','NPeaks', 5)
%-----------------------------------------------------------------------
%-----------------------------------------------------------------------

% load rhythmite data from the southern Bouse Formation
% Figure 3B
% Rhy.mmHoriz  = horizontal rhythmite succession of lime mudstone and
% silt-v.f.g sand

load Rhy.mmHoriz

K = Rhy(:,1);       % layer
R = Rhy(:,2);       % layer thickness
L = Rhy(:,3);       % lithology
nr = length(K);

%logic test to plot lithology in different colors
ind_green_horiz = L==1;    %green silic. silt ? v.f.g. sand
```

```
ind_blue_horiz  = L==0;    %lime mudstone

R_blue = R;
R_blue(ind_green_horiz) = 0;
R_green = R;
R_green(ind_blue_horiz) = 0;

%plot Fig.3B rhythmites
subplot(5,2,3)
 hold on
 bar(K,R_green,'g')
 bar(K,R_blue,'b')
 xlim([0 175])
 set(gca,'TickDir','out')
 title('Horizontal Rhythmites (n=164)')
 xlabel('Rhythmite Layer Number'), ylabel('Thickness (mm)')
 box on

% trend line removed from R "detrending the data"
Line = R(1) + K*(R(nr)-R(1))/(K(nr)-K(1)); % line through 1st & last points
R = R-Line;              % remove trend from R

% Moving average removed from R
wid = 20;
avg = 1+2*wid;          % Assures avg is odd
Z = zeros(wid,1);
Rt = [Z;R;Z];            % temp array with zero padding
Ra = zeros(size(Rt));
for k=wid+(1:nr)
  Ra(k) = mean(Rt(k-wid:k+wid));
end
R = R-Ra(wid+1:wid+nr);

Rfactor=8;
R = interp(R,Rfactor);
Ko= interp(K,Rfactor);

%FFT
FR = fft(R,n4)/n4;    % Fourier transform zero-padded time series
FR = FR*(n4/n);
FR = fftshift(FR);
FR2= 2*FR(nf+1:n4);   % DC to highest non-Nyq. doubled for use of rhs only

%plot Fig.3B FFT
  subplot(5,2,4)
  plot(freq4,abs(FR2))  % amplitude spectrum
  xlim([0.00 2.5])
  ylim([0.00 2.5])
  set(gca,'YTick',[0 1 2])
  set(gca,'TickDir','out')
  title('FFT of Horizontal Rhythmites')
  xlabel('Frequency (cycles/couplet)'), ylabel('Amplitude')
  box on

%[pks, locs]=findpeaks(abs(FR2),freq4,'SortStr','descend','NPeaks', 5) %find
peaks

%-----------------------------------------------------------------------
%-----------------------------------------------------------------------

% load rhythmite data from the southern Bouse Formation
% Figure 3C
```

```
% Rhy.horizmm4  = horizontal rhythmite succession of lime mudstone and
% silt-v.f.g sand


load Rhy.horizmm4

K = Rhy(:,1);       % days (assuming 2 layers/day)
R = Rhy(:,2);       % layer thickness
L = Rhy(:,3);       % lithology
nr = length(K);

%logic test to plot lithologies in different colors
ind_green= L==0;    % green silic. silt - v.f.g. sand
ind_blue= L==1;     % lime mud

R_blue = R;
R_blue(ind_green) = 0;
R_green = R;
R_green(ind_blue) = 0;

%plot Fig.3C rhythmites
subplot(5,2,5)
 hold on
 bar(K,R_green,'g')
 bar(K,R_blue,'b')
 set(gca,'XTick',[0 15 30 45 60 75 90])
  ylim([0 3.5])
  xlim([0 90])
  set(gca,'TickDir','out')
  title('Horizontal Rhythmites (n=87)')
  xlabel('Rhythmite Layer Number'), ylabel('Thickness (mm)')
  box on

% trend line removed from R "detrending the data"
Line = R(1) + K*(R(nr)-R(1))/(K(nr)-K(1)); % line through 1st & last points
R = R-Line;               % remove trend from R

% Moving average removed from R
wid = 20;
avg = 1+2*wid;           % Assures avg is odd
Z = zeros(wid,1);
Rt = [Z;R;Z];             % temp array with zero padding
Ra = zeros(size(Rt));
for k=wid+(1:nr)
  Ra(k) = mean(Rt(k-wid:k+wid));
end
R = R-Ra(wid+1:wid+nr);

Rfactor=8;
R = interp(R,Rfactor);
Ko= interp(K,Rfactor);

%FFT
FR = fft(R,n4)/n4;     % Fourier transform zero-padded time series
FR = FR*(n4/n);
FR = fftshift(FR);
FR2= 2*FR(nf+1:n4);    % DC to highest non-Nyq. doubled for use of rhs only

%plot Fig.3C FFT
  subplot(5,2,6)
  plot(freq4,abs(FR2))  % amplitude spectrum
  set(gca,'TickDir','out')
```

```
  xlim([0.00 2.5])      % 30 days to 3 cycles/day
  ylim([0.0 2])
  title('FFT of Horizontal Rhythmites')
  xlabel('Frequency (cycles/couplet)'), ylabel('Amplitude')
  box on

%[pks, locs]=findpeaks(abs(FR2),freq4,'SortStr','descend','NPeaks', 5) %find
peaks

%-----------------------------------------------------------------------
%-----------------------------------------------------------------------

% load rhythmite data from the southern Bouse Formation
% Figure 3D
% Rhy.mega  = crossbed foresets

load Rhy.mega

K = Rhy(:,1);      % days (assuming 2 layers/day)
R = Rhy(:,2);      % layer thickness
L = Rhy(:,3);      % lithology
nr = length(K);

%logic test to plot lithology in different colors
ind_blue= L==1;    % c.-grained bioclastic grainstone
ind_green= L==0;   % fine-gr. silic rich grainstone

R_blue = R;
R_blue(ind_green) = 0;
R_green = R;
R_green(ind_blue) = 0;

%plot Fig.3D rhythmite
 subplot(5,2,7)
 hold on
 bar(K,R_green,'g')
 bar(K,R_blue,'b')
  xlim([0 80])   % x axis
  set(gca,'TickDir','out')
  title('Crossbed (n=78)')
   xlabel('Rhythmite Layer Number'), ylabel('Thickness (mm)')
  box on

% trend line removed from R
Line = R(1) + K*(R(nr)-R(1))/(K(nr)-K(1)); % line through 1st & last points
R = R-Line;              % remove trend from R

% Moving average removed from R
wid = 20;
avg = 1+2*wid;          % Assures avg is odd
Z = zeros(wid,1);
Rt = [Z;R;Z];            % temp array with zero padding
Ra = zeros(size(Rt));
for k=wid+(1:nr)
  Ra(k) = mean(Rt(k-wid:k+wid));
end
R = R-Ra(wid+1:wid+nr);

Rfactor=8;
R = interp(R,Rfactor);
Ko= interp(K,Rfactor);
```

```
% FFT
FR = fft(R,n4)/n4;    % Fourier transform zero-padded time series
FR = FR*(n4/n);
FR = fftshift(FR);
FR2= 2*FR(nf+1:n4);   % DC to highest non-Nyq. doubled for use of rhs only

% plot Fig.3C FFT
subplot(5,2,8)
  plot(freq4,abs(FR2))  % amplitude spectrum
  xlim([0.00 2.5])   % 30 days to 3 cycles/day
  ylim([0.0 60])
  set(gca,'YTick',[0 25 50])
  set(gca,'TickDir','out')
  title('FFT of Crossbed Rhythmites')
  xlabel('Frequency (cycles/couplet)'), ylabel('Amplitude')
  box on

  %[pks, locs]=findpeaks(abs(FR2),freq4,'SortStr','descend','NPeaks', 5) %find
peaks

%-----------------------------------------------------------------------
%-----------------------------------------------------------------------

% load rhythmite data from the southern Bouse Formation
% Figure 3E
% Rhy.sig = sigmoidal bundle sequence

load Rhy.sig

K = Rhy(:,1);      % layers
R = Rhy(:,2);      % layer thickness
nr = length(K);

%plot Fig.3E Rhythmites
  subplot(5,2,9)
  bar(K,R,'b'), hold on
  set(gca,'TickDir','out')
  xlim([0 36])   % x axis
  title('Sigmoidal Bundles (n=36)')
  xlabel('Rhythmite Layer Number'), ylabel('Thickness (mm)')

% trend line removed from R
Line = R(1) + K*(R(nr)-R(1))/(K(nr)-K(1)); % line through 1st & last points
R = R-Line;              % remove trend from R

% Moving average removed from R
wid = 20;
avg = 1+2*wid;          % Assures avg is odd
Z = zeros(wid,1);
Rt = [Z;R;Z];           % temp array with zero padding
Ra = zeros(size(Rt));
for k=wid+(1:nr)
  Ra(k) = mean(Rt(k-wid:k+wid));
end
R = R-Ra(wid+1:wid+nr);

Rfactor=8;
R = interp(R,Rfactor);
Ko= interp(K,Rfactor);

% FFT
FR = fft(R,n4)/n4;    % Fourier transform zero-padded time series
```

```
FR = FR*(n4/n);
FR = fftshift(FR);
FR2= 2*FR(nf+1:n4);   % DC to highest non-Nyq. doubled for use of rhs only

%plot Fig.3E FFT
  subplot(5,2,10)
  plot(freq4,abs(FR2))  % amplitude spectrum
  xlim([0.03 2.5])      % 30 days to 3 cycles/day
  set(gca,'TickDir','out')
  title('FFT of Sigmoidal Rhythmites')
  xlabel('Frequency (cycles/couplet)'), ylabel('Amplitude')

 %[pks, locs]=findpeaks(abs(FR2),freq4,'SortStr','descend','NPeaks', 5) %find
peaks
%___________________the end_____________________________________________
```

MATLAB CODE – LEAST SQUARES

```
% Matlab Code Supplement Least Squares
% useful for resolving long-wavelength signal
% for 'Tidal rhythmites in the Southern Bouse Formation as evidence for Post-
Miocene uplift of the lower Colorado River corridor'
% Brennan O'Connell, Rebecca J. Dorsey, and Eugene D. Humphreys
% Department of Earth Sciences, University of Oregon, Eugene, Oregon 97403,
USA

%-----------------------------------------------------------------------------
%-----------------------------------------------------------------------------
%-----------------------------------------------------------------------------

clear all


%% Read from specified file
ch= char('horizmm4','mmHoriz','mega','sig');
fprintf('Which one:\n')
for k=1:size(ch,1)
  fprintf('   %d  Rhy.%s\n',k,ch(k,:))
end
test=1;
while test==1
  aaa = input('enter number, then return: ','s');
  aaa = str2double(aaa);
  for k=1:size(ch,1)
    if aaa==k, test=0; break, end
  end
end
pnt = find(ch(aaa,:)~=' ');
Rhy = load(['Rhy.' ch(aaa,pnt)]);

%% Rhythmite input
R  = Rhy(:,2);       % layer thickness
avg= mean(R);
R  = R-avg;

nr = length(R);
t  = (0:nr-1);        % layer, divide by 2

%% Plot Rhythmites
figure(1), clf
subplot(5,2,1)
```

```
  plot(t+1,R ,'k')  % "+1" so first point is 1
    axis tight
    yl = get(gca,'YLim');   dy=yl(2)-yl(1);
    set(gca,'YLim',[yl(1)-0.1*dy yl(2)+0.1*dy])
  title(['Rhy.' ch(aaa,pnt)])
  xlabel('layer number')

%% Least squares for [DC,As,Ac] in  R = D + As*sin(wt) + Ac*cos(wt)
inc = 0.0005;
buffer = 0.004;
lim = floor((1-2*buffer)/inc);
f  = NaN(1,lim);
DC = NaN(1,lim);
amp= NaN(1,lim);
for k=10:lim                % lower limit above 1 to avoid longest-period part
  f(k) = buffer+k*inc;      % at Nyq when freq=0.5 (ie, 1 cycle per 2 layers)
  s = sin(2*pi*f(k)*t/2);   % /2 to put into days (at 2 layers per day)
  c = cos(2*pi*f(k)*t/2);
  ss= s.*s;
  sc= s.*c;
  cc= c.*c;
  A = [sum(s) sum(ss) sum(sc); ...     % A*CC = P
       sum(c) sum(sc) sum(cc); ...
        nr    sum(s)  sum(c)];
  P = [s*R c*R sum(R)]';
  CC = A\P;                            % invert for CC
  D  = CC(1);
  As = CC(2);
  Ac = CC(3);
  Rp = D + As*s + Ac.*c;
  DC(k) = D;
  amp(k)= sqrt(As^2+Ac^2);
end

%% plot Amplitude spectrum
subplot(5,2,1)
  plot(f*2,amp)
  title('Spectrum')
  ylim([0 .2]) %this y-axis must change depending on the rhythmite analyzed
  xlabel('Frequency (cycles/couplet)')
subplot(5,2,2)
    nn = 20:ceil(lim/8);
    plot(f(nn)*2,amp(nn)), axis tight, hold on
    plot(f(nn)*2,DC(nn))   % plots the DC offset
  plot(get(gca,'XLim'),[0 0],'k'), hold off
  xlabel('Period (couplets/cycle)')
  title('Low Frequency Enlargement')
    xx = get(gca,'XTick');
    xx = round(10./xx)/10;
    set(gca,'XTickLabel',xx)
    yl = get(gca,'YLim');
    set(gca,'YLim',[0 yl(2)*1.15])

   [pks, locs]=findpeaks(amp(nn),f(nn)*2,'SortStr','descend','NPeaks', 5)

%___________________the end_____________________________________________
%____________________________________________________________________
```

Data Repository for
Tidal Rhythmites in the Southern Bouse Formation as Evidence for Post-Miocene Uplift of the Lower Colorado River Corridor
Brennan O'Connell, Rebecca J. Dorsey, Eugene D. Humphreys

Modern Tidal Data (used in Figure 3A)

Names in parentheses (Tides.in) refer to target data in Matlab code (supplemental file)

Figure 3A. (Tides.in)

```
% Modern tidal data one
month of modern tide
record at San Felipe, Gulf
of California, March, 1993

125 196
141 185
171 207
210 185
232 193
264 195
286 210
318 178
344 200
364 189
392 218
421 171
446 211
470 180
495 226
522 163
548 219
573 171
598 230
625 154
650 225
676 160
700 236
727 157  % 29 283
%repeat of peak
54  364  %   line 25
80  285
106 372
131 281 %
156 371
183 279  % full moon
208 372
233 279
259 369
285 280
311 366
335 285
361 370
387 284
412 360
437 290
463 364
490 291
515 348
539 298
565 357
593 298
618 338
641 307
668 349
698 305
720 330  % 22  463
%repeat of trough
46  447  %   line 52
74  471
108 442
139 459
159 454
185 468
217 440
245 468
268 449
292 472
320 434
348 473
371 443
394 477
422 430
449 476
471 438
497 482
523 428
549 479
574 427
597 484
625 426
650 485
675 429
700 487
726 429  % 27  559
%repeat of peak
52  620  %   line 79
78  559
103 621
129 557
154 623
180 558
205 622
230 557
256 626
281 552  % new moon
306 619
331 557
357 625
383 555
408 619
432 560
458 626
484 556
509 614
533 562
558 624
585 559
609 608
634 565
659 619
687 563
```

711 605
733 579 % 36 702
%repeat of peak
63 747 % line 107
92 701
116 732 % 121 726
%ends 28 days
138 710
167 744
196 707
221 725
241 714
270 737
304 709
333 723
353 717
381 736
410 704
% END
% dX=698 is 7 days
% dy=97 is 7 meters

Rhythmite Thickness Data (used in Figure 3B-E)

Names in parentheses (Rhy.xxx) refer to target data in Matlab code (supplemental file)

Figure 3B. Horizontal *(n=162)* (Rhy.mmHoriz)
Location
33.26326°, -114.63597°

Layer#: Thickness(mm): Lithology (0=lime mud 1=silic. silt-v. fine gr. sand)

1	0.689	0
2	1.465	1
3	0.517	0
4	1.381	1
5	0.603	0
6	1.121	1
7	0.577	0
8	0.864	1
9	0.46	0
10	1.034	1
11	0.46	0
12	2.068	1
13	0.402	0
14	0.804	1
15	0.517	0
16	1.437	1
17	0.517	0
18	1.035	1
19	0.691	0
20	0.632	1
21	0.517	0
22	1.608	1
23	0.603	0
24	0.775	1
25	0.577	0
26	0.632	1
27	0.345	0
28	0.574	1
29	0.517	0
30	0.689	1
31	0.46	0
32	0.747	1
33	0.632	0
34	0.634	1
35	0.634	0
36	1.149	1
37	0.46	0
38	0.919	1
39	0.349	0
40	0.402	1
41	4.423	1
42	0.431	0
43	0.646	1
44	0.689	0
45	1.508	1
46	0.345	0
47	0.906	1
48	0.56	0
49	1.206	1
50	0.388	0
51	0.689	1
52	0.56	0
53	2.671	1
54	0.431	0
55	0.646	1
56	0.689	0
57	1.508	1
58	0.345	0
59	0.906	1
60	0.56	0
61	1.206	1
62	0.388	0
63	0.689	1
64	0.56	0
65	2.671	1
66	0.388	0
67	1.465	1
68	0.388	0
69	0.862	1
70	0.431	0
71	0.648	1
72	0.431	0
73	1.336	1
74	0.519	0
75	0.474	1
76	0.433	0
77	0.562	1
78	0.56	0
79	0.474	1
80	0.39	0
81	0.517	1
82	0.691	0
83	0.948	1
84	0.56	0
85	1.293	1
86	0.605	0
87	0.82	1
88	0.646	0
89	1.637	1

90	0.431	0
91	0.646	1
92	0.689	0
93	1.508	1
94	0.345	0
95	0.906	1
96	0.56	0
97	1.206	1
98	0.388	0
99	0.689	1
100	0.56	0
101	2.671	1
102	0.388	0
103	1.465	1
104	0.388	0
105	0.862	1
106	0.431	0
107	0.648	1
108	0.431	0
109	1.336	1
110	0.519	0
111	0.474	1
112	0.433	0
113	0.562	1
114	0.56	0
115	0.474	1
116	0.39	0
117	0.517	1
118	0.691	0
119	0.948	1
120	0.56	0
121	1.293	1
122	0.605	0
123	0.82	1
124	0.646	0
125	1.637	1
126	0.345	0
127	0.905	1
128	0.39	0
129	1.077	1
130	0.474	0
131	1.422	1
132	0.819	0
133	1.422	1
134	0.474	0
135	0.862	1
136	0.388	0
137	0.562	1
138	0.56	0
139	1.379	1
140	0.732	0
141	1.25	1
142	0.906	0
143	0.948	1
144	0.603	0
145	0.648	1
146	0.605	0
147	1.724	1
148	0.345	0
149	0.734	1
150	0.431	0
151	0.691	1
152	0.431	0
153	1.767	1
154	0.476	0
155	1.508	1
156	0.388	0
157	0.691	1
158	0.388	0
159	0.56	1
160	0.517	0
161	0.517	1
162	0.302	0

Figure 3C. Horizontal (*n=87)* (Rhy.horizmm4)
Location
33.26326°, -114.63597°

Layer#: Thickness(mm): Lithology (0=lime mud 1=silic. silt-v. fine gr. sand)

1	0.362	1
2	2.412	0
3	0.362	1
4	0.784	0
5	0.241	1
6	2.11	0
7	0.603	1
8	1.507	0
9	0.543	1
10	0.543	0
11	0.301	1
12	0.844	0
13	0.543	1
14	0.422	0
15	0.663	1
16	0.482	0
17	0.482	1
18	0.543	0
19	0.301	1
20	0.543	0
21	0.543	1
22	0.904	0
23	0.784	1
24	0.904	0
25	0.543	1
26	0.543	0
27	0.271	1
28	1.628	0
29	0.844	1
30	0.422	0
31	0.422	1
32	1.206	0
33	0.482	1
34	1.507	0
35	0.784	1
36	1.387	0
37	0.543	1
38	0.724	0
39	0.482	1
40	0.362	0
41	0.482	1
42	1.447	0
43	1.025	1
44	1.146	0
45	0.844	1
46	0.965	0
47	0.784	1
48	0.904	0
49	0.482	1
50	1.568	0
51	0.663	1
52	0.844	0
53	0.301	1

54	0.904	0
55	0.543	1
56	1.629	0
57	0.543	1
58	1.748	0
59	0.482	1
60	0.784	0
61	0.241	1
62	0.362	0
63	0.422	1
64	0.422	0
65	0.543	1
66	0.814	0
67	0.543	1
68	0.909	0
69	0.181	1
70	0.724	0
71	0.663	1
72	1.869	0
73	0.663	1
74	0.724	0
75	0.606	1
76	0.965	0
77	0.301	1
78	1.326	0
79	0.603	1
80	0.603	0
81	0.543	1
82	0.603	0
83	0.422	1
84	1.025	0
85	0.422	1
86	0.543	0
87	0.482	1

Figure 3D. Crossbed (*n=78)* (Rhy.mega)

Location:
33.269795°, -114.637463°

Layer#: Thickness(mm): Lithology (0= fine-gr. silic.-rich grainstone, 1= c.-gr. bioclastic grainstone)

1	15	0
2	10	1
3	20	0
4	15	1
5	30	0
6	50	1
7	20	0
8	10	1
9	15	0
10	10	1
11	15	0
12	10	1
13	30	0
14	5	1
15	3.5	1
16	4	1
17	4	1
18	4	1
19	4	1
20	5.5	1
21	20	0
22	10	1
23	20	0
24	10	1
25	40	0
26	25	1
27	23	0
28	10	1
29	25	0
30	10	1
31	50	0
32	15	1
33	30	0
34	8	1
35	40	0
36	20	1
37	11	1
38	10	1
39	11	1
40	9	1
41	9	1
42	9	1
43	10	1
44	11	1
45	20	1
46	45	0
47	10	1
48	15	0
49	6	1
50	10	0
51	5	1
52	20	0
53	6	1
54	30	0
55	9	1
56	7.5	1
57	6	1
58	6.25	1
59	6.25	1
60	6.25	1
61	6.25	1
62	8.5	1
63	45	1
64	85	0
65	15	1
66	55	0
67	15	1
68	65	0
69	8.5	1
70	8	1
71	7	1
72	7	1
73	6	1
74	7	1
75	8	1
76	8.5	1
77	45	0
78	30	1

Figure 3E. Sigmoidal Bundles (*n=36)* (Rhy.sig)

Location:
33.2896°, -114.6324°

Layer#: Thickness(mm)

1	10
2	12
3	6
4	2
5	3
6	32
7	33
8	9
9	5
10	50
11	30
12	17
13	65
14	20
15	37
16	45
17	10
18	15
19	20
20	7
21	5
22	4
23	30
24	14
25	25
26	50
27	80
28	40
29	20
30	10
31	8
32	3
33	20
34	12
35	10
36	8