Sigsbee2 Models

Trevor Irons

Data Type: *2D model and acoustic finite difference synthetic data set with constant density*
Source: *SMAART consortium comprised of BHPBilliton Petroleum, BP, and the Chevron-Texaco Exploration and Production Technology Company*
Location: *http://www.delphi.tudelft.nl/SMAART/sigsbee2a.htm*
Format: *SEGY and Native*
Date of origin: *Data were publicly released between September 2001 and November 2002.*

INTRODUCTION

The Subsalt Multiples Attenuation and Reduction Technology Joint Venture (SMAART JV) publicly released several data sets between September 2001 and November 2002. These synthetic data model the geologic setting found on the Sigsbee escarpment in the deep water Gulf of Mexico. Additional information may be found at: *www.delphi.tudelft.nl/SMAART/*. The data sets remain the property of SMAART and are used under the agreement found at the SMAART site listed above.

The file *sigsbee/FILES* lists all files contained in the Sigsbee2 repository of Madagascar and is reproduced below in Table 1. Any of these files may be downloaded to local machines using ftp protocols.

The Sigsbee2 data are separated into two distinct categories, A and B. They share the same general model geometry and structure, however, the A model has a soft water to seafloor boundary while the B model features a more realistic hard boundary. As a result data produced in the B model features multiple events. The Sigsbee2B data set was featured in paper SP3.8 "Observations from the Sigsbee2B synthetic data set" at the 2002 SEG meeting in Salt Lake City.

SIGSBEE MODELS

This model contains a sedimentary sequence broken up by a number of normal and thrust faults. Additionally, there is a complex salt structure found within the model that results in illumination problems when processing and migrating the data.

The Sigsbee2A model features an absorbing free surface condition and a weaker than normal water bottom reflection, resulting in data do not contain free surface multiples and less than normal internal multiples. The Sigsbee 2B model uses the same structural model as Sigsbee2A but the velocity contrast at the water bottom has been increased to a normal level thus generating significant internal and free surface multiples. Modeling on the 2B model was performed with both free and non free surface boundary conditions.

```
-rwxr-xr-x    1 root     root     952751760 2005-04-20 07:42 sigsbee2a_nfs.sgy
-rwxr-xr-x    1 root     root     10762452 2005-04-20 07:42 sigsbee2a_migvel.sgy
-r-xr-xr-x    1 root     root     951254160 2005-04-20 07:44 sigsbee2b_fs.segy
-rwxr-xr-x    1 root     root         1226 2005-04-20 07:44 sigsbee2a_README.txt
-rwxr-xr-x    1 root     root        32768 2005-04-20 07:44 sigsbee2a_readme.doc
-rwxr-xr-x    1 root     root      1425920 2005-04-20 07:44 sigsbee2a.ppt
-rwxr-xr-x    1 root     root     16149444 2005-04-20 07:44 sigsbee2a_stratigraphy.sgy
-rwxr-xr-x    1 root     root     10762452 2005-04-20 07:44 sigsbee2a_migration_velocity.sgy
-r-xr-xr-x    1 root     root       213561 2005-04-20 07:44 sigsbee2b_migration_velocity.jpg
-rwxr-xr-x    1 root     root     16149444 2005-04-20 07:44 sigsbee2a_reflection_coefficients.sgy
-r-xr-xr-x    1 root     root     10762452 2005-04-20 07:44 sigsbee2b_migration_velocity.segy
-r-xr-xr-x    1 root     root       335994 2005-04-20 07:45 sigsbee2b_reflection_coefficients.jpg
-r-xr-xr-x    1 root     root         7668 2005-04-20 07:45 sigsbee2b_readme.txt
-r-xr-xr-x    1 root     root        34816 2005-04-20 07:45 sigsbee2b_readme.doc
-r-xr-xr-x    1 root     root     951254160 2005-04-20 07:45 sigsbee2b_nfs.segy
-r-xr-xr-x    1 root     root       245888 2005-04-20 07:45 sigsbee2b_stratigraphy.jpg
-r-xr-xr-x    1 root     root       317044 2005-04-20 07:45 sigsbee2b_stratigraphy_index.jpg
-r-xr-xr-x    1 root     root     16149444 2005-04-20 07:45 sigsbee2b_reflection_coefficients.segy
-r-xr-xr-x    1 root     root      3000402 2005-04-20 07:45 zoff.hh
-r-xr-xr-x    1 root     root       315609 2005-04-20 07:45 sigsbee2b_zero_offset_nfs.jpg
-r-xr-xr-x    1 root     root       314983 2005-04-20 07:45 sigsbee2b_zero_offset_mp.jpg
-r-xr-xr-x    1 root     root       365901 2005-04-20 07:45 sigsbee2b_zero_offset_fs.jpg
-r-xr-xr-x    1 root     root     16149444 2005-04-20 07:45 sigsbee2b_stratigraphy.segy
-r-xr-xr-x    1 root     root     169120541 2005-06-10 03:42 SRC0t_sparse.hh
-r-xr-xr-x    1 root     root     84560571 2005-06-10 03:42 SRC0x_sparse.hh
-r-xr-xr-x    1 savap    users    84560571 2005-06-10 03:44 SRC0x.hh
-r-xr-xr-x    1 savap    users    84560571 2005-06-10 03:44 SRC1x.hh
-r-xr-xr-x    1 savap    users    84560571 2005-06-10 03:44 SRC2x.hh
-r-xr-xr-x    1 savap    users    169120541 2005-06-10 03:44 SRC0t.hh
-r-xr-xr-x    1 savap    users    169120541 2005-06-10 03:45 SRC1t.hh
-r-xr-xr-x    1 savap    users    169120541 2005-06-10 03:46 SRC2t.hh
```

Table 1: List of all available files in the Madagascar Sigsbee2 repository

The Sigsbee2 models found in the Madagascar repository share the same dimensions and sampling rate. The model is 9.144 km (30 000 ft) in depth and 24.384 km (80 000 ft) in length. All the models contain 7.62 m (25 ft) grid spacing except for the migrated models that have 11.43 m (37.5 ft) lateral grid spacing. Throughout this article both standard and metric units will be presented in tabular form but all figures will exclusively utilize metric units.

Table 2 displays the correct values that Sigsbee2 model headers should contain.

Sigsbee 2A Models

The Sigsbee2A velocity and reflection coefficient models are easily viewed using Madagascar. There are 2 velocity models, a smooth migrated model and a true stratigraphic model. The SCons script *sigsbee/model2A/SConstruct* contains a set of rules that tell Madagascar to fetch the data append the headers and make several plots. This script is reproduced in Table 3.

Typing Command 1 within the *sigsbee/model2A* directory runs the script.

```
bash-3.1$ scons view
```
(1)

The Sigsbee2A migrated and stratigraphic velocity models are shown in Figures 1a and 1b respectively. A plot of the reflection coefficients are shown in Figure 1c.

Stratigraphic Models				
Standard Units				
n1=1201	d1=25	o1=0	label1=Depth	unit1=ft
n2=3201	d2=25	o2=10000	label2=Distance	unit2=ft
Metric Units				
n1=1201	d1=.00762	o1=0	label1=Depth	unit1=km
n2=3201	d2=.00762	o2=3.048	label2=Distance	unit2=km
Migrated Models				
Standard Units				
n1=1201	d1=25	o1=0	label1=Depth	unit1=ft
n2=2133	d2=37.5	o2=10025	label2=Distance	unit2=ft
Metric Units				
n1=1201	d1=.00762	o1=0	label1=Depth	unit1=km
n2=2133	d2=.0143	o2=3.055	label2=Distance	unit2=km

Table 2: Header information for Sigsbee2 models, note the initial offset in the horizontal direction and the coarse lateral sampling of the migrated models.

```
from rsf.proj import *

 ######################################
 # Sigsbee 2A velocity model construct #
 ######################################

PRFX = 'sigsbee2a_'
SUFX = '.sgy'

for c in ('migration_velocity','stratigraphy','reflection_coefficients'):
    if(c=='migration_velocity'):
        v='vmig2A'
        o=3.055
        d=.01143
        s=.0003048
        l='Migration\ Velocity'
        a='y'
        u='km/s'
    if(c=='stratigraphy'):
        v='vstr2A'
        o=3.048
        d=.00762
        s=.0003048
        l='Stratigraphic\ Velocity'
        a='y'
        u='km/s'
    if(c=='reflection_coefficients'):
        v='reflectionCoefficients'
        o=3.048
        d=.00762
        s=1
        l='Reflection\ Coefficients'
        a='n'
        u=''
    h = c + 'head'
    t = PRFX + c + SUFX
    Fetch(t,'sigsbee')

    Flow([v,h],t,
         '''
         segyread tfile=${TARGETS[1]} |
         put
         o1=0  d1=.00762   label1=Depth    unit1=km
         o2=%f d2=%f       label2=Distance unit2=km
         | scale rscale=%f
         ''' %(o,d,s))

    Result(v,v,'''window f1=1 | grey color=i scalebar=y allpos=%s screenratio=.375 screenht=3 barreverse=y
    wheretitle=t title=%s labelsz=4 titlesz=6 barlabel=Velocity barunit=%s''' % (a,l,u))

End()
```

Table 3: Contents of *model2A/SConstruct* script.

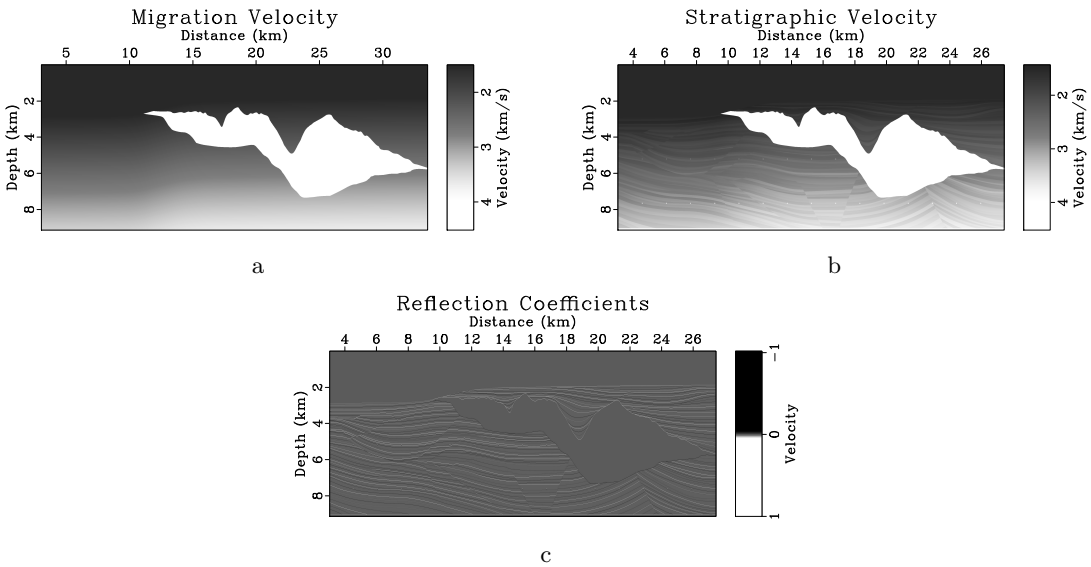


Figure 1: Sigsbee 2A contains a stratigraphic velocity model (a) a migrated smoothed model (b) and a reflection coefficient model (c).

Sigsbee 2B Models

The Sigsbee 2B model contains the same general geometry as the 2A model except for a more realistic water to floor boundary which results in multiple generation when shots are modeled on it. However, dealing with the files is basically identical the headers should also be calibrated as shown in Table 2.

Table 4 shows the contents of the *sigsbee/model2b/SConstruct* script. This file is quite similar to the one found in the Sigsbee 2A section and contains a list of rules that fetch the datasets and plot them.

Typing Command 2 within the *sigsbee/model2B* directory runs the script.

```
bash-3.1$ scons view
```
(2)

A plot of the migrated velocity model is shown below Figure 2b while the stratigraphic model can be seen in Figure 2a. A plot of the reflection coefficients are shown in Figure 2c.

SHOT RECORDS

Several sets of data were acquired on the Sigsbee models. The Madagascar repository contains one survey taken on the Sigsbee2A model which was performed with an absorbing surface boundary condition. Two surveys were conducted on the Sigsbee2B models one with a free surface boundary and one without.

The three surveys shared the same acquisition geometry. Each receiver recorded data every .008 seconds for 1 500 timesteps resulting in 12 seconds of data. A 7 950 m (26 100 ft) long streamer cable was deployed with 348 hydrophones spaced 22.86 m (75 ft) apart.

```
from rsf.proj import *

 ######################################
 # Sigsbee 2B velocity model construct #
 ######################################

PRFX = 'sigsbee2b_'
SUFX = '.segy'

for c in ('migration_velocity','stratigraphy','reflection_coefficients'):

    if(c=='migration_velocity'):
        v='vmig2B'
        o=3.055
        d=.0143
        s=.0003048
        l='Migration\ Velocity'
        a='y'
        u='\(km\/s\)'
    if(c=='stratigraphy'):
        v='vstr2B'
        o=3.048
        d=.00762
        s=.0003048
        l='Stratigraphic\ Velocity'
        a='y'
        u='\(km\/s\)'
    if(c=='reflection_coefficients'):
        v='reflectionCoefficients2B'
        o=3.048
        d=.00762
        s=1
        l='Reflection\ Coefficients'
        a='n'
        u=''
    h = c + 'head'
    t = PRFX + c + SUFX
    Fetch(t,'sigsbee')

    Flow([v,h],t,
         '''
         segyread tape=$SOURCE tfile=${TARGETS[1]} |
         put
         o1=0  d1=.00762   label1=Depth     unit1=km
         o2=%f d2=%f       label2=Distance  unit2=km
         | scale rscale=%f
         ''' %(o,d,s) ,stdin=0)

    Result(v,v,'''grey color=i scalebar=y allpos=%s screenratio=.375 screenht=3
                  wheretitle=t title=%s labelsz=4 titlesz=6 barlabel=%s''' % (a,l,u))

End()
```

Table 4: Contents of *model2B/SConstruct* script.

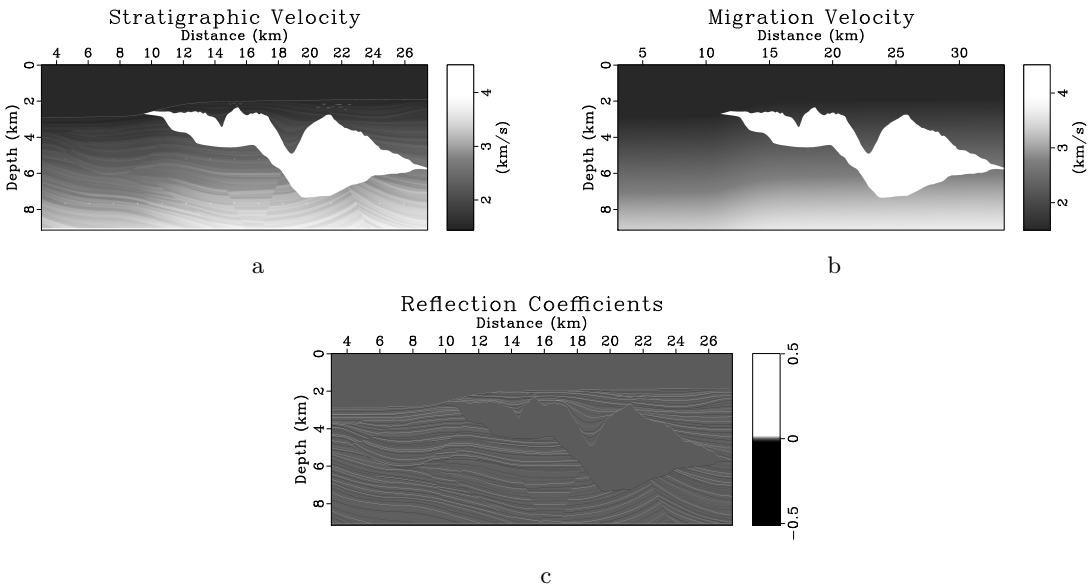


Figure 2: Sigsbee 2B contains two velocity models, a stratigraphic model (a) and a migrated model(b). The resulting reflection coefficients are shown in (c).

Shots were fired every 45.72 m (150 ft) starting at 3 330 m (10 925 ft). Table 5 shows the values that Sigsbee shot headers should contain.

Standard				
n1=1500	d1=0.008	o1=0	label1=Time	unit1=s
n2=348	d2=75	o2=0	label2=Offset	unit2=ft
n3=500 or 496	d3=150	o3=10925	label3=Shot-Coord	unit3=ft
Metric				
n1=1500	d1=0.008	o1=0	label1=Time	unit1=s
n2=348	d2=.02286	o2=0	label2=Offset	unit2=km
n3=500 or 496	d3=.04572	o3=3.330	label3=Shot-Coord	unit3=km

Table 5: Appropriate header values for Sigsbee shot records. The number of shots; n3, varies slightly between the surveys

Sigsbee 2A shot records

The survey performed on the Sigsbee2A model had an infinite surface boundary condition. The script found at *data2A/SConstruct* whose contents are displayed in Table 6 generates a Madagascar formatted data file *shots.rsf* and also produces several shot images.

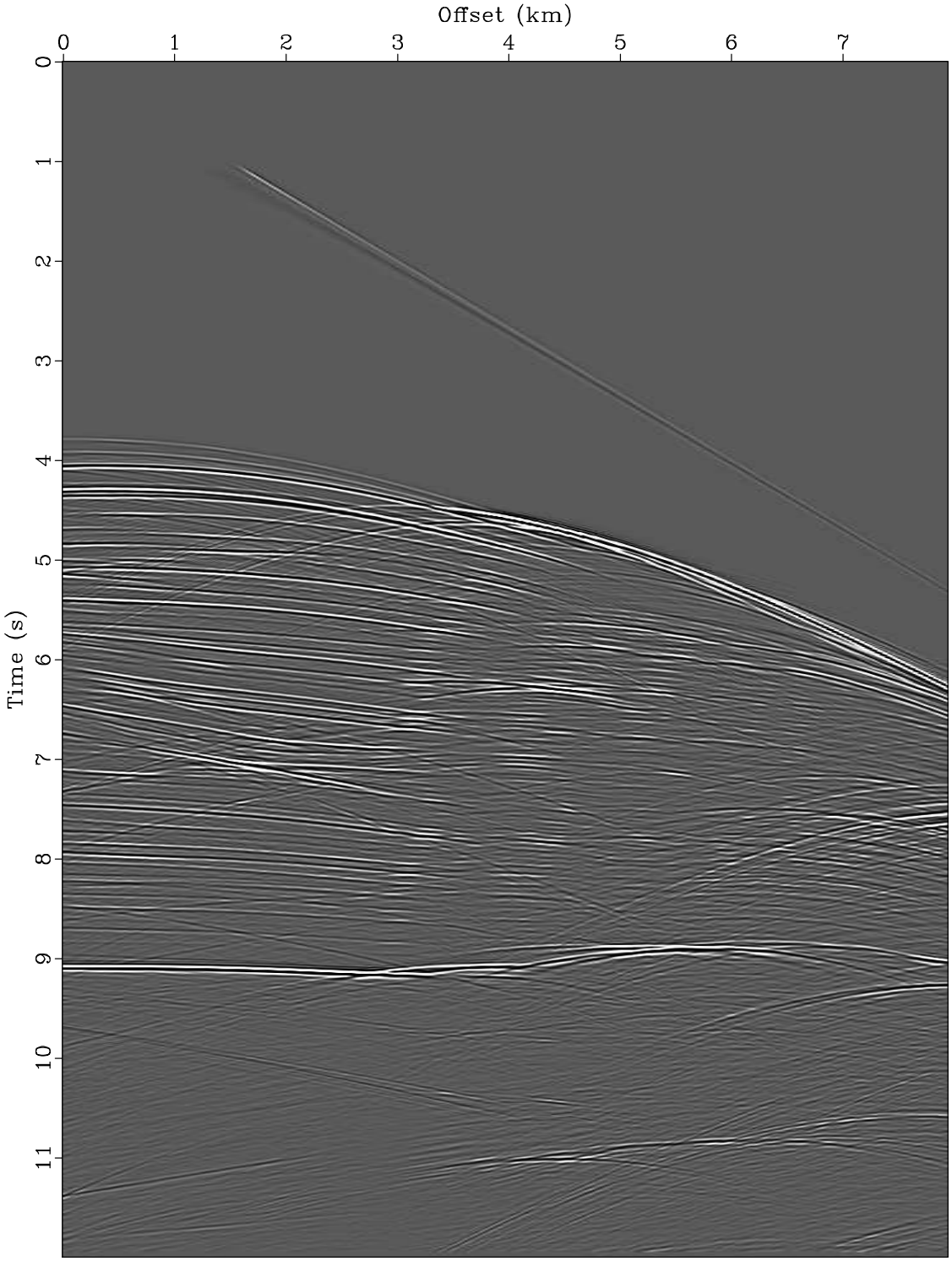
Typing Command 3 within the *sigsbee/data2A* directory runs the script.

```
bash-3.1$ scons view
```
(3)

A plot of the 70th shot, made 6.5 km in to the model is produced by the *SConstruct* script and is shown below in Figure 3 The zero offset data is presented in Figure 4.

```
    ###########################
    #   Sigsbee 2A Shot Data   #
    ###########################
from rsf.proj import *
#------- Define Variables and Filenames -------#
data = 'sigsbee2a_nfs.sgy'


#------------- Import Data --------------------#
#-- Uses ftp program Fetch
Fetch(data ,'sigsbee')


#----------  Convert Data ----------------------#
Flow('zdata tzdata ./dhead ./bdhead',data,
     '''
     segyread
     tfile=${TARGETS[1]}
     hfile=${TARGETS[2]}
     bfile=${TARGETS[3]}
     ''')

# create sraw(t,o,s): o=full offset, s=shot position, t=time

Flow('ss','tzdata','dd type=float | headermath output="10925+fldr*150" | window')
Flow('oo','tzdata','dd type=float | headermath output="offset"         | window')
Flow('si','ss','math output=input/150')
Flow('oi','oo','math output=input/75')
Flow('os','oi si','cat axis=2 space=n ${SOURCES[1]} | transp | dd type=int')
Flow('sraw','zdata os',
     '''
     intbin head=${SOURCES[1]} xkey=0 ykey=1
     ''')
Flow('shot','sraw',
     '''
     put
                            label1=Time        unit1=s
        d2=.02286 o3=0      label2=Offset      unit2=km
        d3=.04572 o3=3.330  label3=Shot-coord  unit3=km |
     mutter half=false t0=1.0 v0=6000
     ''')

#---------------- Plot Data ----------------#
Result('zero','shot',
       '''
       window  min2=0 max2=0 size2=1 |
       grey  pclip=98 color=I screenratio=1.5 gainpanel=a
       label2=Position label1=Time title= label3=  unit2=km unit1=s
       labelsz=3
       ''')


Result('shot70','shot',
       '''
       window n3=1 f3=70 |
       grey  pclip=99 color=I gainpanel=a wantframenum=y  unit1=s label1=Time
       label2=Offset unit2=km label3=Shot unit3=km title=
       screenratio=1.35 labelsz=3
       ''')
End()
```

Table 6: Contents of *data2A/SConstruct* script.



6.5304

Figure 3: Snapshot of shot number 70 performed on *sigsbee 2A* the position of the source in km is in the lower left hand corner of the plot.

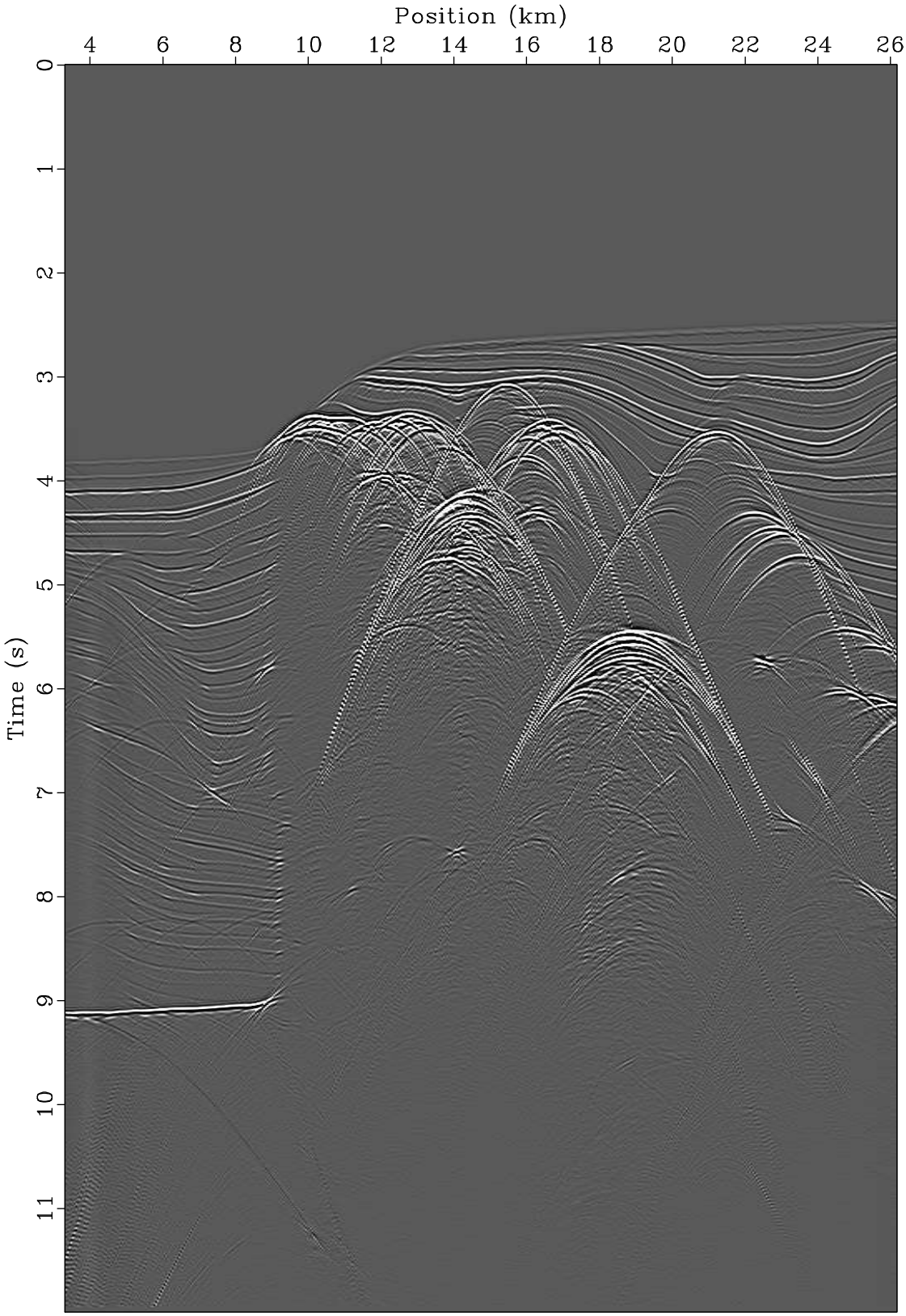


Figure 4: Sigsbee2A zero offset data

Sigsbee 2B Shot Records

The Sigsbee 2B library contains two sets of shot data, *nfs* and *fs*. These shots were modeled with free and non free surface boundary conditions.

Free surface model

A *SConstruct* script found at *sigsbee/data2B/fs/* is presented in Table 7. This script reads the *segy* source file and converts it to Madagascar's *RSF* format and appends the header as necessary. The free surface boundary present within this model allows for the generation of reflections at the model edges.

```
 ######################################
 # Sigsbee 2B Free Surface Shot Data   #
 ######################################

from rsf.proj import *

#------- Define Variables and Filenames -------#
data = 'sigsbee2b_fs.segy'

#------------- Import Data --------------------#
#-- Uses ftp program Fetch
Fetch(data ,'sigsbee')


#---------  Convert Data --------------------#
Flow('zdata tzdata ./dhead ./bdhead',data,
      '''
      segyread
      tape=$SOURCE
      tfile=${TARGETS[1]}
      hfile=${TARGETS[2]}
      bfile=${TARGETS[3]}
      ''',stdin=0)

# create sraw(t,o,s): o=full offset, s=shot position, t=time

Flow('ss','tzdata','dd type=float | headermath output="10925+fldr*150" | window')
Flow('oo','tzdata','dd type=float | headermath output="offset"          | window')
Flow('si','ss','math output=input/150')
Flow('oi','oo','math output=input/75')
Flow('os','oi si','cat axis=2 space=n ${SOURCES[1]} | transp | dd type=int')
Flow('sraw','zdata os',
      '''
      intbin head=${SOURCES[1]} xkey=0 ykey=1
      ''')
Flow('shotFs2B','sraw',
      '''
      put
                              label1=Time        unit1=s
         d2=.02286 o3=0       label2=Offset      unit2=km
         d3=.04572 o3=3.330 label3=Shot-coord unit3=km |
      mutter half=false t0=1.0 v0=6000
      ''')



#---------------- Plot Data ----------------#
Result('zero2Bfs','shotFs2B','''window $SOURCE min2=0 max2=0 size2=1
     | grey  pclip=98 color=I screenratio=1.5 gainpanel=a
     label2=Position label1=Time title= label3=  unit2=km unit1=s
     labelsz=3''')


Result('shot702Bfs','shotFs2B','''window $SOURCE n3=1 f3=70 |
     grey  pclip=99 color=I gainpanel=a wantframenum=y  unit1=s label1=Time
     label2=Offset unit2=km label3=Shot unit3=km title=
     screenratio=1.35 labelsz=3''')

End()
```

Table 7: Contents of *data2B/fs/SConstruct* script.

Again shot number 70, fired 6.5 km into the model, is plotted in Figure 5. The precise

coordinates of the shot are shown in the lower left hand corner of the figure. The zero offset data is presented in Figure 6.

Infinite Surface Model

This data was prepared with the boundaries of the model extending forever; as such multiples are not created as a result of the model edges.

A *SConsctuct* script found at *sigsbee/data2B/fs/* is presented in Table 8. This script translates the *segy* source data file and converts it into *rsf* format.

```
 ########################
 # Sigsbee 2B Shot Data  #
 ########################
from rsf.proj import *

#------- Define Variables and Filenames -------#
data = 'sigsbee2b_nfs.segy'

#------------- Import Data --------------------#
#-- Uses ftp program Fetch
Fetch(data ,'sigsbee')

#---------  Convert Data ---------------------#
Flow('zdata tzdata ./dhead ./bdhead',data,
     '''
     segyread
     tape=$SOURCE
     tfile=${TARGETS[1]}
     hfile=${TARGETS[2]}
     bfile=${TARGETS[3]}
     ''',stdin=0)

# create sraw(t,o,s): o=full offset, s=shot position, t=time

Flow('ss','tzdata','dd type=float | headermath output="10925+fldr*150" | window')
Flow('oo','tzdata','dd type=float | headermath output="offset"          | window')
Flow('si','ss','math output=input/150')
Flow('oi','oo','math output=input/75')
Flow('os','oi si','cat axis=2 space=n ${SOURCES[1]} | transp | dd type=int')
Flow('sraw','zdata os',
     '''
     intbin head=${SOURCES[1]} xkey=0 ykey=1
     ''')
Flow('shotNfs2B','sraw',
     '''
     put
                          label1=Time       unit1=s
        d2=.02286 o3=0    label2=Offset     unit2=km
        d3=.04572 o3=3.330 label3=Shot-coord unit3=km |
     mutter half=false t0=1.0 v0=6000
     ''')

#---------------- Plot Data ----------------#
Result('zero2Bnfs','shotNfs2B','''window $SOURCE min2=0 max2=0 size2=1
    | grey  pclip=98 color=I screenratio=1.5 gainpanel=a
    label2=Position label1=Time title= label3=  unit2=km unit1=s
    labelsz=3''')


Result('shot702Bnfs','shotNfs2B','''window $SOURCE n3=1 f3=70 |
    grey  pclip=99 color=I gainpanel=a wantframenum=y  unit1=s label1=Time
    label2=Offset unit2=km label3=Shot unit3=km title=
    screenratio=1.35 labelsz=3''')

End()
```

Table 8: Contents of *data2B/nfs/SConstruct* script.

Similar plots are produced for this model. Figure 7 shows an image of shot number 70 taken at 6.5 km into the model. Figure 8 displays the zero offset data acquired on this model.

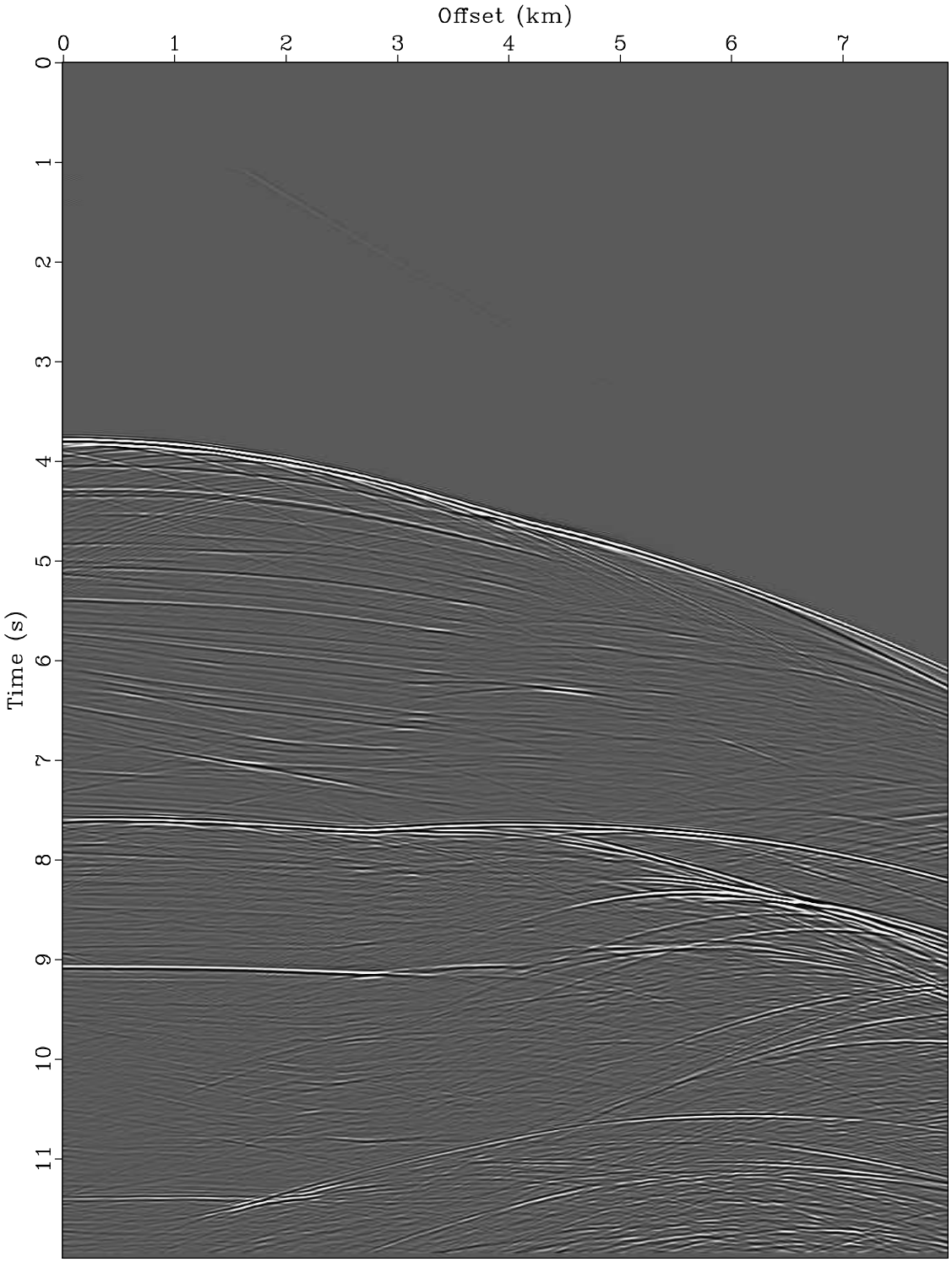


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Figure 5: Shot number 70 performed on *sigsbee 2B FS* model. The shot location is presented in the lower left hand corner of the plot

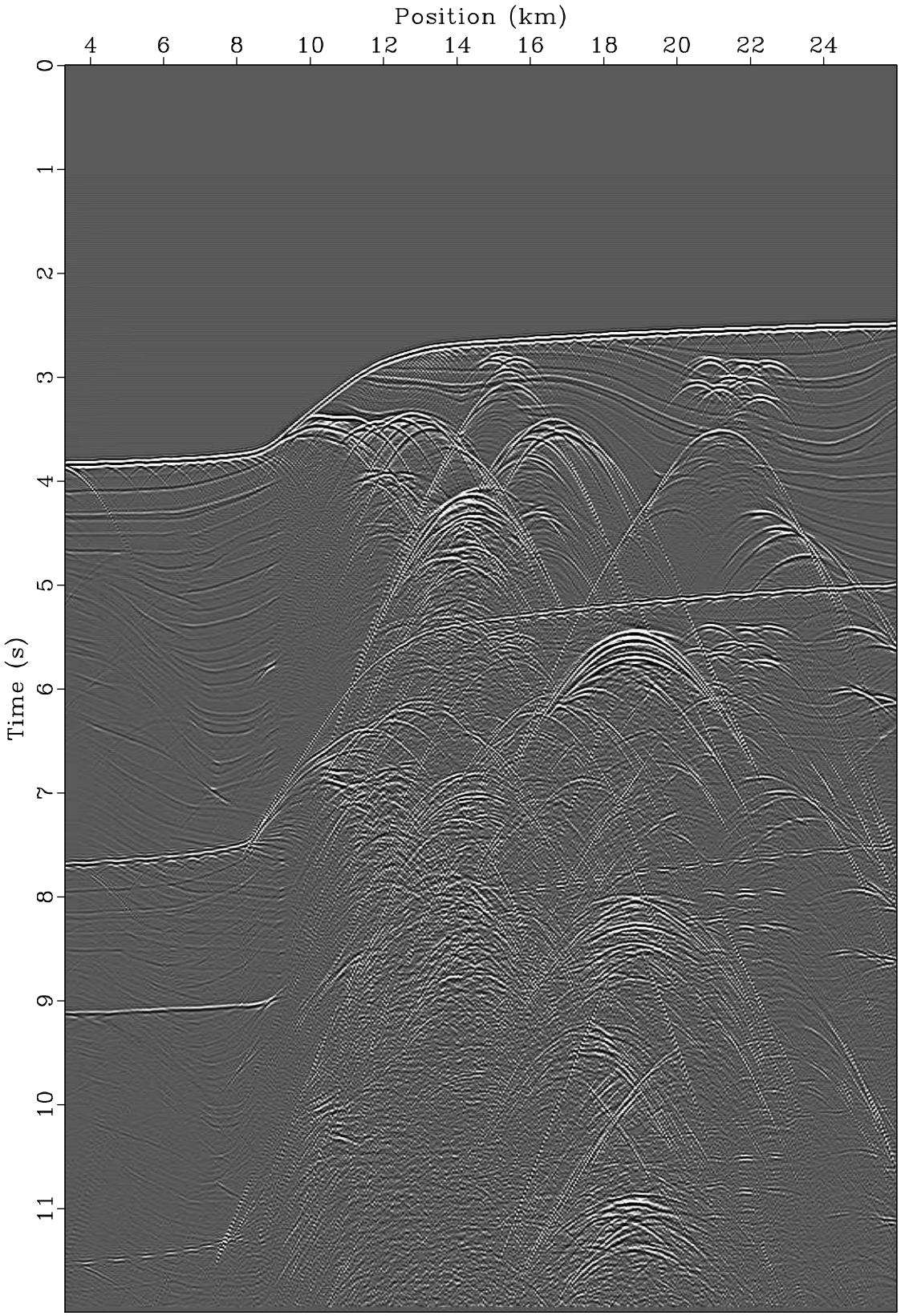

Figure 6: Sigsbee2B free surface boundary zero offset data.

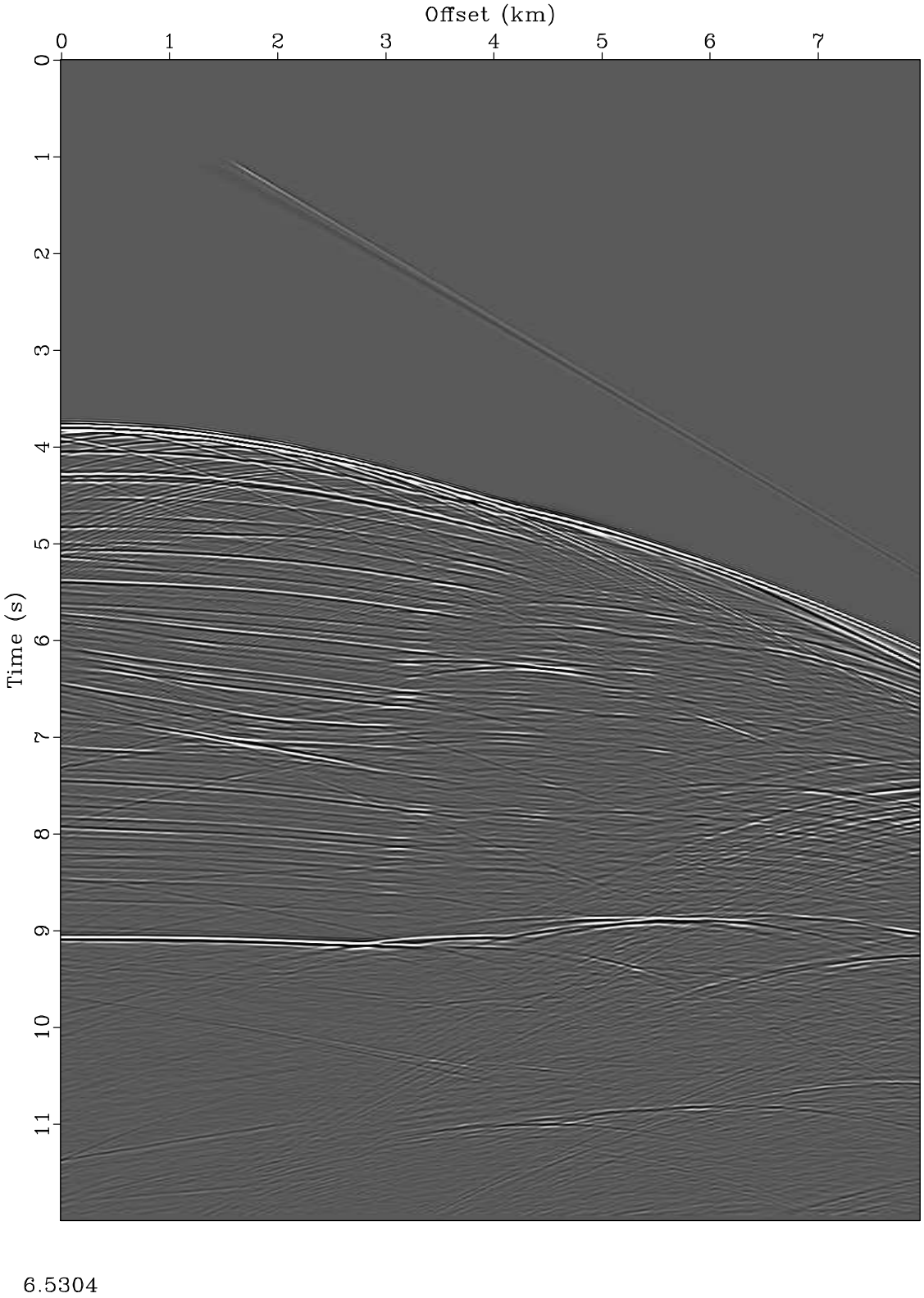

Figure 7: Shot 70 performed in *Sigsbee 2B NFS* model.

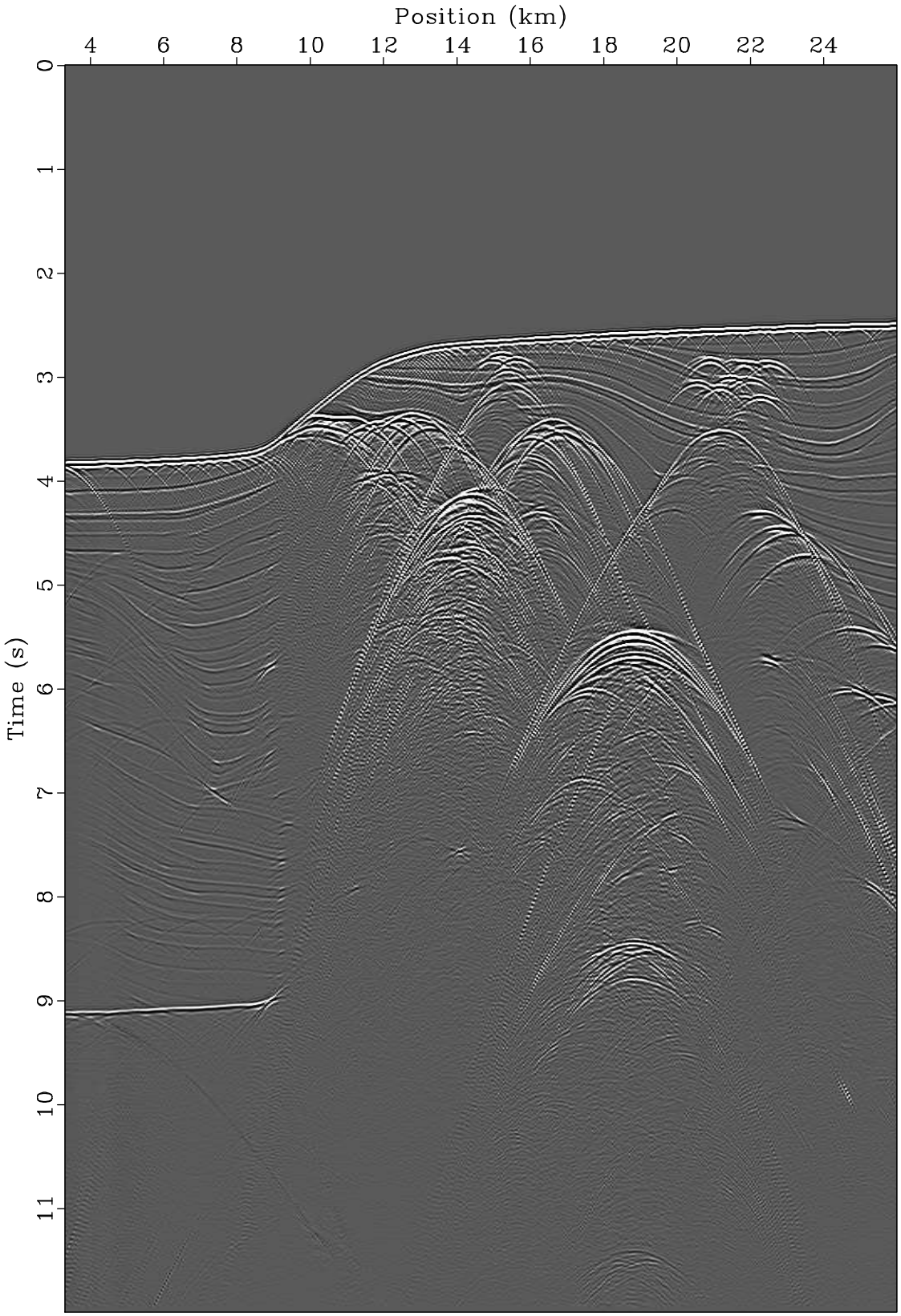

Figure 8: Sigsbee 2B reflecting surface zero offset data, notice the decreased multiples from the free surface model

FINITE DIFFERENCE MODELING

Finite difference (FD) shot and data modeling can be performed on the Sigsbee models using Madagascar. This example will use the Sigsbee2A model but but it could be easily extended to perform modeling on Sigsbee2B.

For the purposes of this example a shot will be fired at 10 km along the horizontal coordinate and at a depth of 10 meters. Receivers are spread at a depth of 0 meters every 7.62 m (25 ft) along the entire scope of the model. This long receiver cable is impractical but useful for these purposes. Data is recorded on every receiver at time increments of 1 ms 3000 times resulting in 3 seconds of data.

An *SConstruct* file located within *sigsbee/fdmod2A/* properly formats the model and inputs necessary parameters to perform a shot on the Sigsbee model. This file is reproduced below in Table 9.

Typing Command 4 within the *sigsbee/fdmod2A/* directory runs the FD modeling script.

```
bash-3.1$ scons view                    (4)
```

This script first constructs the survey acquisition geometry as was previously mentioned. An image of the survey is created and presented in Figure 9.

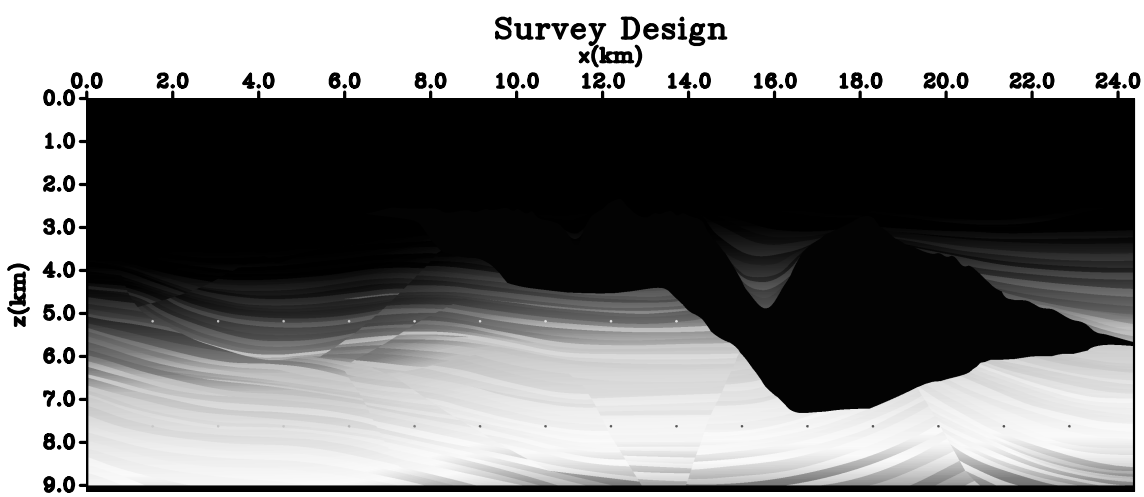

Figure 9: FD model geometry as performed on the Sigsbee 2A velocity model. The X represents the shot while the smaller * symbols represent receivers. The receivers extent along the right hand side although it is not clear in this image.

Firing the shot results the propagation of a wavefield which can be seen in the movie *wfl.vpl* that is generated. Typing Command 5 within the *sigsbee/fdmod2A* directory displays the wavefield movie.

```
bash-3.1$ scons wfl.vpl                 (5)
```

Four frames from this movie are presented in Figure 10 illustrating the propagation of the wavefield in the model.

```
from rsf.proj import *
import fdmod
##
 # Sigsbee 2A
##
data='sigsbee2a_stratigraphy.sgy'
Fetch(data,'sigsbee')
Flow(['vstr2A','vstr2Ahead'],data,
          '''
          segyread tape=$SOURCE tfile=${TARGETS[1]} |
          put
          o1=0  d1=25      label1=z unit1=ft
          o2=10000 d2=25  label2=x unit2=ft
          ''',stdin=0)
# ------------------------------------------------------------
par = {
     'nt':7000, 'dt':0.001,'ot':0,     'lt':'t','ut':'s',
     'kt':100,     # wavelet delay
     'nx':3201, 'ox':0, 'dx':0.00762, 'lx':'x','ux':'km',
     'nz':1201, 'oz':0, 'dz':0.00762, 'lz':'z','uz':'km',
     }
# add F-D modeling parameters
fdmod.param(par)
# ------------------------------------------------------------
# wavelet
Flow('wav',None,
          '''
          spike nsp=1 mag=1 n1=%(nt)d d1=%(dt)g o1=%(ot)g k1=%(kt)d |
          ricker1 frequency=15 |
          scale axis=123 |
          put label1=t label2=x label3=y |
          transp
          ''' % par)
Result('wav',
        'transp | window n1=200 | graph title="" label1="t" label2= unit2=')
# ------------------------------------------------------------
# experiment setup
Flow('r_',None,'math n1=%(nx)d d1=%(dx)g o1=%(ox)g output=0' % par)
Flow('s_',None,'math n1=1       d1=0       o1=0       output=0' % par)
# receiver positions
Flow('zr','r_','math output="0" ')
Flow('xr','r_','math output="x1"')
Flow('rr',['xr','zr'],
      '''
      cat axis=2 space=n
      ${SOURCES[0]} ${SOURCES[1]} | transp
      ''', stdin=0)
Plot('rr',fdmod.rrplot('',par))
# source positions
Flow('zs','s_','math output=.01')
Flow('xs','s_','math output=10.0')
Flow('rs','s_','math output=1')
Flow('ss',['xs','zs','rs'],
      '''
      cat axis=2 space=n
      ${SOURCES[0]} ${SOURCES[1]} ${SOURCES[2]} | transp
      ''', stdin=0)
Plot('ss',fdmod.ssplot('',par))

# ------------------------------------------------------------

# Velocity
Flow('vel','vstr2A',
      '''
      scale rscale=.0003048 |
      put o1=%(oz)g d1=%(dz)g  o2=%(oz)g d2=%(dz)g
      ''' % par)

Plot('vel',fdmod.cgrey('''
allpos=y bias=1.5 pclip=100 color=j title=Survey\ Design labelsz=4 titlesz=6 wheretitle=t
''',par))
Result('vel',['vel','rr','ss'],'Overlay')

# ------------------------------------------------------------

# density
Flow('den','vel','math output=1')

# ------------------------------------------------------------
# finite-differences modeling
fdmod.awefd('dat','wfl','wav','vel','den','ss','rr','free=y dens=y',par)

Plot('wfl',fdmod.wgrey('pclip=99 title=Wavefield\ Movie labelsz=4 titlesz=6 wheretitle=t',par),view=1)

times=['1','2','3','4']
cntr=0
for item in ['9','19','29','39']:
     Result('time'+item,'wfl',
            '''
            window f3=%s n3=1 min1=0 min2=0 | grey gainpanel=a
            pclip=99 wantframenum=y title=Wavefield\ at\ %s\ s labelsz=4
            titlesz=6 screenratio=.375 screenht=2 wheretitle=t
            label1=z label2=x unit1=kft unit2=kft
            ''' % (item,times[cntr]))
     cntr = cntr + 1
Result('dat','window j2=4 j1=2 | transp |' + fdmod.dgrey('pclip=99',par))
End()
```

Table 9: *Seismic script that performs a finite-difference synthetic shot on Sigsbee2A*

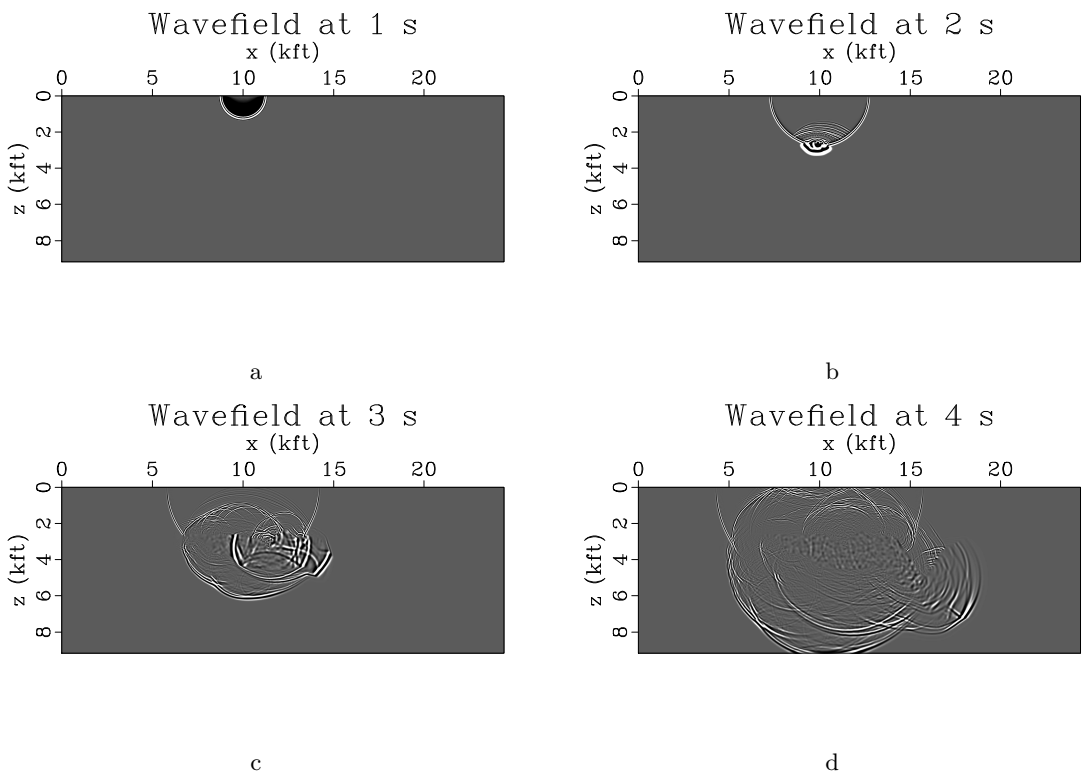

Figure 10: Images of the propagating wavefield in the Sigsbee model generated by a finite difference model.

The resulting data is then presented in the file *dat.vpl*. This plot is reproduced here in Figure 11.

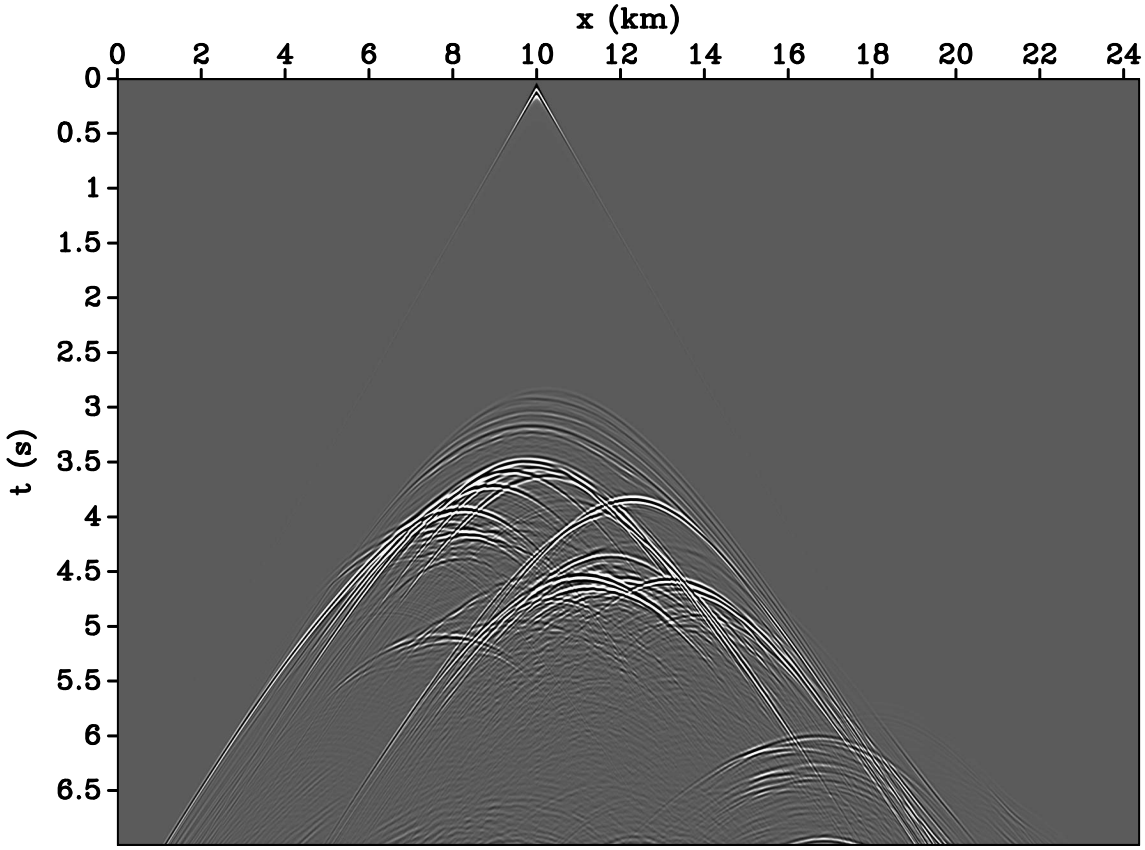

Figure 11: Data gathered by the receivers in the FD model survey.

FD models can be performed on the Sigsbee2B model in a similar fashion. The primary change would be in appending line six, the model input file, in the *SConstruct* file shown in Table 9.