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.
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
```

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

<table>
<thead>
<tr>
<th></th>
<th>Standard Units</th>
<th>Metric Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stratigraphic Models</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>n1=1201</strong></td>
<td><em>d1=25</em> o1=0 label1=Depth unit1=ft</td>
<td><em>d1=.00762</em> o1=0 label1=Depth unit1=km</td>
</tr>
<tr>
<td><strong>n2=3201</strong></td>
<td><em>d2=25</em> o2=10000 label2=Distance unit2=ft</td>
<td><em>d2=.00762</em> o2=3.048 label2=Distance unit2=km</td>
</tr>
<tr>
<td><strong>Migrated Models</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>n1=1201</strong></td>
<td><em>d1=25</em> o1=0 label1=Depth unit1=ft</td>
<td><em>d1=.00762</em> o1=0 label1=Depth unit1=km</td>
</tr>
<tr>
<td><strong>n2=2133</strong></td>
<td><em>d2=37.5</em> o2=10025 label2=Distance unit2=ft</td>
<td><em>d2=.0143</em> o2=3.055 label2=Distance unit2=km</td>
</tr>
</tbody>
</table>

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
```

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 r sf.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='\(\text{km/s}\)'
    if c == 'stratigraphy':
        v='vstr2B'
        o=3.048
        d=.00762
        s =.0003048
        l='Stratigraphic\ Velocity'
        a='y'
        u='\(\text{km/s}\)'
    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,
    ssgyread tape=$SOURCE tfile=${TARGETS[1]} |
pit
    o1=0 d1=.00762 label1=Depth unit1=km
    o2=%f d2=%f label2=Distance unit2=km
    scale rscale=%f
    \%o,d,a,stdin=0

Result(v,v,'grey color=i scalebar=y allpos=%s screenratio=.375 screenht=3
    \% where title=t title=%s labelsz=4 title2z=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.

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

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
```

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.
```plaintext
from rsf.proj import *

# Define Variables and Filenames

# Sigsbee 2A Shot Data

data = 'sigsbee2a_nfs.sgy'

# Uses ftp program Fetch

Fetch(data , 'sigsbee')

# Convert Data

Flow( 'zdata tzdata ./dhead ./bhead', data, ...
  sgyread
tfile=${TARGETS[1]}
hfile=${TARGETS[2]}
bfile=${TARGETS[3]}
''')

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

Flow( 'ss', 'tdata', 'dd type=double | headermath output="10925+flidr*150" | window' )
Flow( 'oo', 'tdata', 'dd type=double | 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 ${TARGETS[1]} | transpose | dd type=int' )
Flow( 'sraw', 'zdata os', ...
  intbin head=${TARGETS[1]} xkey=0 ykey=1 ''')
Flow( 'shot', 'sraw', ...
  put
  d2=0.02286 a3=0 label2=Offset unit2=km
  d3=0.04572 o3=3.330 label3=Shot coord unit3=km |
  matter half=false t0=1.0 v0=6000 ''')

# Plot Data

Result( 'zero', 'shot', ...
  window min2=0 max2=2 size2=1 |
  gray pclip=98 color=1 screenratio=1.5 gainpanel=a
  label2=Position label1=Time title=label3=unit2=km unit1=s
  label2=3 ''')
Result( 'shot70', 'shot', ...
  window n3=1 f3=70 |
  gray pclip=99 color=1 gainpanel=a wantframenums=y unit1=s label1=Time
  label2=Offset unit2=km label3=Shot unit3=km title=
  screenratio=1.35 label2=3 ''')
End()
```

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

```
# SConstruct script found at sigsbee/data2B/fs/
from rsf.proj import *

data = 'sigsbee2b_fs.segy'

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 .dhead .bhead', data, segyread)

Flow('tzdata', 'dd type=float | headermath output="10925+fldr*150" | window')

Flow('oo', 'tzdata', 'dd type=float | headermath output="offset" | window')

Flow('ss', 'oo', 'math output=input/150')

Flow('oi', 'oo', 'math output=input/75')

Flow('os', 'oi si', 'math axis=2 space=\$[SOURCES[1]] | transp | dd type=int')

Flow('sraw', 'os', '

intbin head=\$[SOURCES[1]] xkey=0 ykey=1

...')

Flow('shotFs2B', 'sraw', '...

put

d2=0.2286 o3=0 label2=Offset unit2=km

d3=0.04572 o3=3.330 label3=Shot coord unit3=km |
mutter half=false t0=1.0 v0=6000

...')

# Plot Data

Result('zero2Bfs', 'shotFs2B', '...

Result('shot702Bfs', 'shotFs2B', '...

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 SConstruct 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.

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.
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 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
```

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

![Survey Design](image)

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
```

Four frames from this movie are presented in Figure 10 illustrating the propagation of the wavefield in the model.
Table 9: Scen 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.](image)

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.