Time Lapse Seismic Modeling

SAGD (enhanced oil recovery)

<table>
<thead>
<tr>
<th>Region</th>
<th>Heavy oil</th>
<th>Natural bitumen</th>
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<tbody>
<tr>
<td>North America</td>
<td>35.3</td>
<td>530.9</td>
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- Natural bitumen 32%
- Conventional Oil 47%
- Heavy oil 21%

10° C

90° C
Case 1: Steam Chamber

4D Seismic Coverage

SAGD Well Map View

SAGD Hz Well Pair -1

SAGD Hz Well Pair -2

Field Acquisition Parameters

Source/Receiver Line Spacing: 45 m
Source/Receiver Station Interval: 15 m
3D Bin Size: 7.5 m
Orthogonal Cross Spread Shooting Geometry
SAGD Well Cross-Section

170 mMD
Sand/shale
V_p=2,200 m/s, V_p/V_s=2.1, ρ=2.25 kg/m^3

180 mMD
Sand
V_p=2,100 m/s, V_p/V_s=2.0, ρ=2.05 kg/m^3

210 mMD
Carbonate
V_p=4,300 m/s, V_p/V_s=1.8, ρ=2.5 kg/m^3

SAGD Steam Chamber

Production well
Injection well
Source/Receiver Line Spacing: 45 m
Source/Receiver Station Interval: 15 m
Symmetric, far offset 255m, 35 receivers, 32 sources
Wavelet Rikker, 100Hz

“Model CW” across wells

Vp=2000m/s; Vs=1050m/s; Dens=2.25 g/cm^3
Vp=2100m/s; Vs=1050m/s; Dens=2.05 g/cm^3
Vp=1800m/s; Vs=800m/s; Dens=1.95 g/cm^3
Vp=1700m/s; Vs=700m/s; Dens=1.80g/cm^3
Vp=4300m/s; Vs=2390m/s; Dens=2.50 g/cm^3

“Model AW” along wells

Well

Well
Before SAGD

“Model CW” across wells

Well

After SAGD

PSDM for synthetic data:

After SAGD

Difference: After SAGD - Before

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Before SAGD

After SAGD

"Model AW" along wells

PSDM for synthetic data:

Before SAGD

After SAGD

Difference: After SAGD - Before
From very initial 2D modeling for two models along and across horizontal well it can be noticed:

✓ Source/receiver spacing 45/15m may be too sparse for good enough imaging of SAGD zone, especially in direction across horizontal well.

✓ Should be achieved record frequency 200-300 Hz for good enough resolution of SAGD zone, correspondingly sampling rate should be 0.2-0.5 msec.

✓ Time lapse 4D survey theoretically can provide information about SAGD zone, especially across well direction.

✓ Along well direction there is quite considerable interference (for ≤100Hz) of reflection from bottom of SAGD zone and top of carbonates, which may prevent recognition of bottom of SAGD zone, even using 4D time lapse data.
Case 2: “SAGD-Induced cavity in oil sands”

20 m receiver interval
Source peak Frequency 140Hz, wavelet Rikker

Initial Model: a) building using with pad image; b) resulting (pad image invisible)
Duplex waves:
Green arrows – monotypic P-P
Yellow – converted P-S and S-P

T=360 ms

T=470 ms
Case 2: Summary

- Used frequency band 140-160 Hz allows to clearly identify events from modeled “cavity” on synthetic shotgathers.
- For survey with bin size 20m, special processing procedures may be required to image such kind of sub-vertical features.
- Time lapse 4D survey with bin size 10-20m theoretically can provide information about SAGD-induced cavernous zones (with relatively mild difference in seismic impedance with surrounding rocks) from about 3 and more meters width at depth 400-500 m.