Across the Mediterranean basins, the Messinian salinity crisis resulted in the deposition of up to 2 km thick multi-layered evaporitic succession consisting of alternating layers of halite and clastics [2, 3]. Such geological objects obscure seismic imaging and may even be over pressurized posing potential drilling hazards, which are often hard to predict [4]. We demonstrate TPDOT&TWSM approach developed in IPGG SB RAS by example of evaluating the interference wavefields wave fragment into the shadow zone for real geological case from the Levant Basin, offshore Israel. Using of GPUs allowed accelerating TWSM algorithm based on multiple large size matrix-vector operations in hundreds and more times.

**THE EXPERIMENTAL MODEL**

We analyzed complex intra-salt structures within the Messinian evaporites from a three-dimensional, depth-migrated, seismic reflection volume from the Levant Basin, offshore Israel (Figure 1).

In the black circle, we have identified the clastics under consideration and the corresponding seismic blanking spot: Structure of the experimental model includes five layers: 3 clastic and 2 halite layers in between (Figure 2, left). We assumed that all layers are homogeneous and of severe curvature (Figure 2, right).

Medium and geometrical properties were taken from borehole data analyzed in [2]. We put a plane wave source at the sea surface and receivers line beneath the source. The edges E1, E2 and E3 of interfaces C1, C2 and C3, respectively, cause the edge diffraction waves. Similarly to optics, the seismic blanking in ME1 occurs due to the interference of the wavefield: the transmitted wave through C1, C2 and C3 and the edge-diffractions waves at E1, E2 and E3 all together give very weak wave amplitude; the image based on the low amplitude wave is therefore unclear (Figure 2). By that reason we observe the shadow in ME1.

**TPDOT&TWSM APPROACH**

Transmission-Propagation-Diffraction Operator Theory (TPDOT) [1] describes in explicitly analytic form propagation of the seismic wavefields in 3D block-layered geologic media by action of two operators: 1) transmission operator (reflection/refraction) \( \mathbf{T} \) at curved interface, 2) propagation operator \( \mathbf{P} \) inside block/layer. Tip-Wave Superposition Method (TWSM) [5] being the mid-frequency range approximation of TPDOT. TWSM computes the wave amplitude functions \( \mathbf{a} \) at receivers by multiple multiplication of large scale matrices \( \mathbf{P} \) and \( \mathbf{T} \) and wave amplitude function \( \mathbf{a} \) for source wavefield at interface \( \mathbf{C}_i \). For model Figure 2 wave amplitude function at receivers reflected from ME1 can be represented as matrix-vector multiplication:

\[
\mathbf{a} = \mathbf{P} \mathbf{a}^s \cdot \mathbf{T} \mathbf{h}_i \cdot \mathbf{T} \mathbf{h}_c \cdot \mathbf{P} \mathbf{h}_c \mathbf{P} \mathbf{h}_c \mathbf{P} \mathbf{h}_c \mathbf{P} \mathbf{h}_c \mathbf{T} \mathbf{h}_c \mathbf{T} \mathbf{a}^s.
\]

Matrix \( \mathbf{P} \) describes propagation from elements of clastic interface \( \mathbf{C}_i \) to elements of clastic interface \( \mathbf{C}_j \). Matrix \( \mathbf{T} \) describes reflection from halite layer \( h_i \) in layer \( h_j \) through the clastic layer. Matrix \( \mathbf{T}_{hc} \) describes reflection from clastic layer ME1. Each wave amplitude vector in the frequency domain demands to repeat matrix-vector multiplications (1) for each discrete frequency \( \mathbf{\phi} \) of some frequency array \( \mathbf{\phi} \). Acceleration of each matrix-vector multiplication is realized on GPUs with help of scheme, shown on Figure 3. Each GPU accelerometer processes multiplication of group of matrix strips corresponding to frequencies \( \mathbf{\phi} \) by group of wave amplitude vectors. Finally TPDOT GPUs gather new transformed group of wave amplitude vectors via exchange by computed data. Since matrix dimension is \( x \times n \) – \( n \times n \), then TWSM algorithm adapted for GPUs can potentially keep any number of available GPUs but no more than \( N \). Curve of scalability the TWSM algorithm is demonstrated on Figure 4.

**COMPUTATION RESULTS**

Using TPDOT&TWSM, we obtained the reflected wave from ME1 (Figure 5). The modeling result confirms in that the middle of the seismogram the amplitudes are very weak (we had to zoom the seismogram 500 times for the traces to become visible: the red circle in Figure 5). It is obvious that the inversion of such a wavefield resulted in the shadow zone in ME1 of Figure 1. Therefore, in order to obtain a better image, the diffracted wave must be extracted from the interference wavefield. Since it has high amplitude its inversion will give enough illumination in the shadow.

Table below model computation time at 8 kernels of Intel Xeon 2.53 GHz CPUs in comparison to computation times on 3, 12, 24 and 30 NVIDIA Tesla M2090 GPUs with Fermi-architecture.

<table>
<thead>
<tr>
<th>GPU Type</th>
<th>Intel Xeon 2.53 GHz (8 kernels)</th>
<th>3 GPUs</th>
<th>12 GPUs</th>
<th>24 GPUs</th>
<th>30 GPUs</th>
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</thead>
<tbody>
<tr>
<td>Computation time (min)</td>
<td>120</td>
<td>20.4</td>
<td>5.8</td>
<td>3.2</td>
<td>2.8</td>
</tr>
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**REFERENCES**