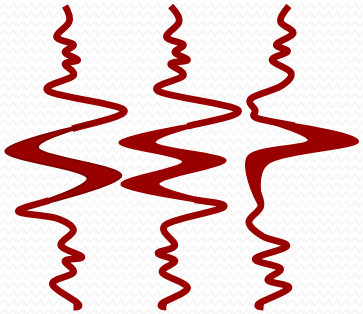
Enhanced salt-body segmentation by shape deformation

Yang Zhang and Adam D. Halpert

SEP147, p297

May, 2012



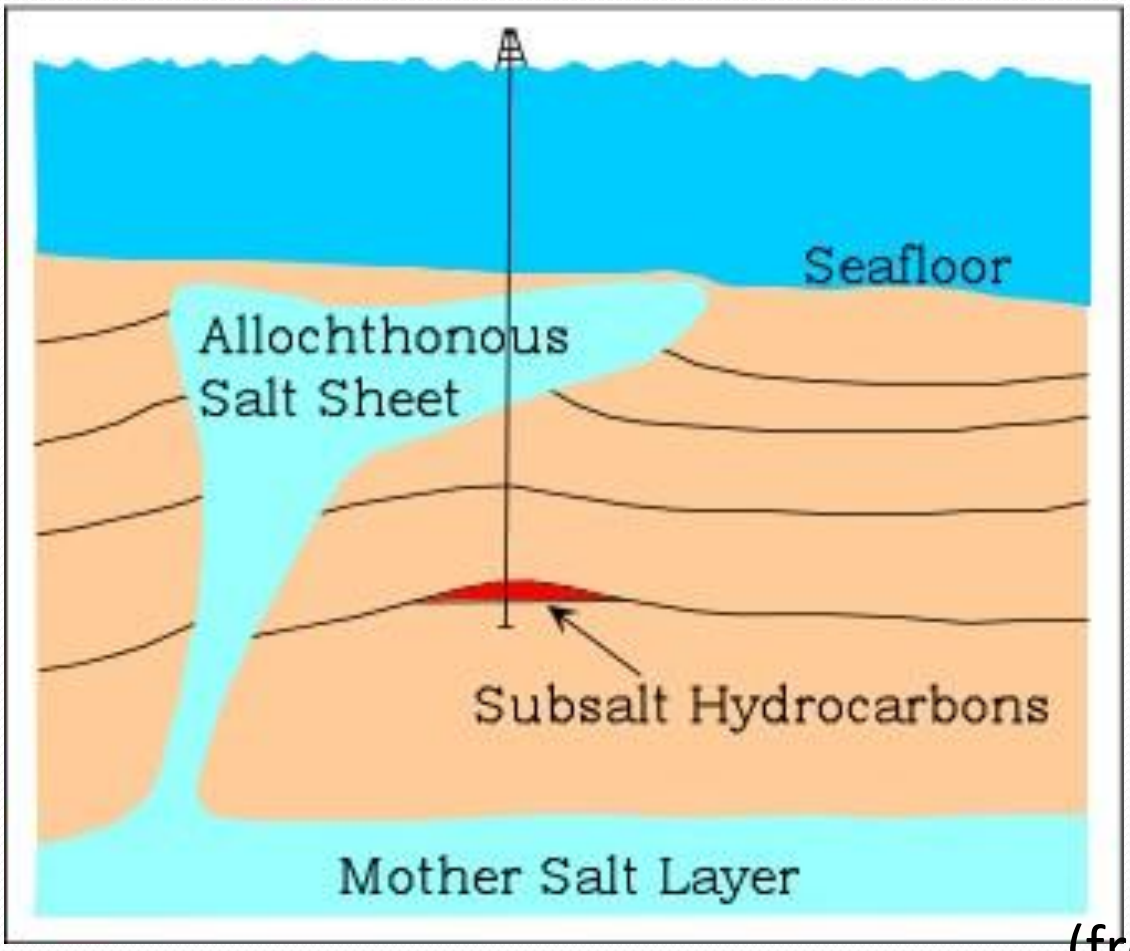
Stanford Exploration Project

Outline

- Motivation: why do we propose a semi-automatic segmentation method?
- Problem: how to make most use of the limited amount of manual interpretation?
- Previous solution: cross-slice smearing
- New solution: boundary deformation
- GOM 3-D seismic image example
- Discussions & conclusion

Why subsalt areas are important?

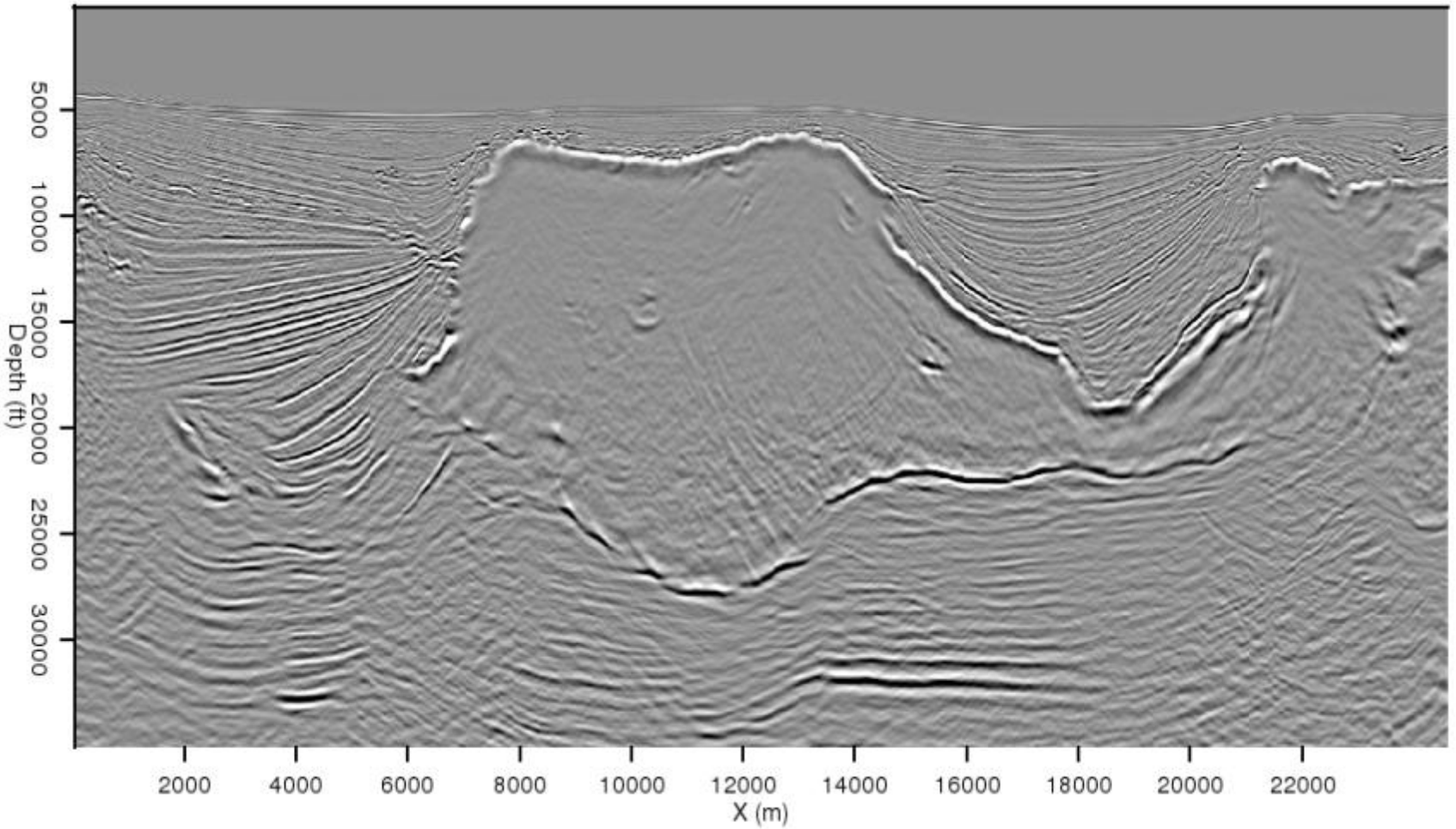
- Subsalt areas have become key points of interests for oil and gas exploration



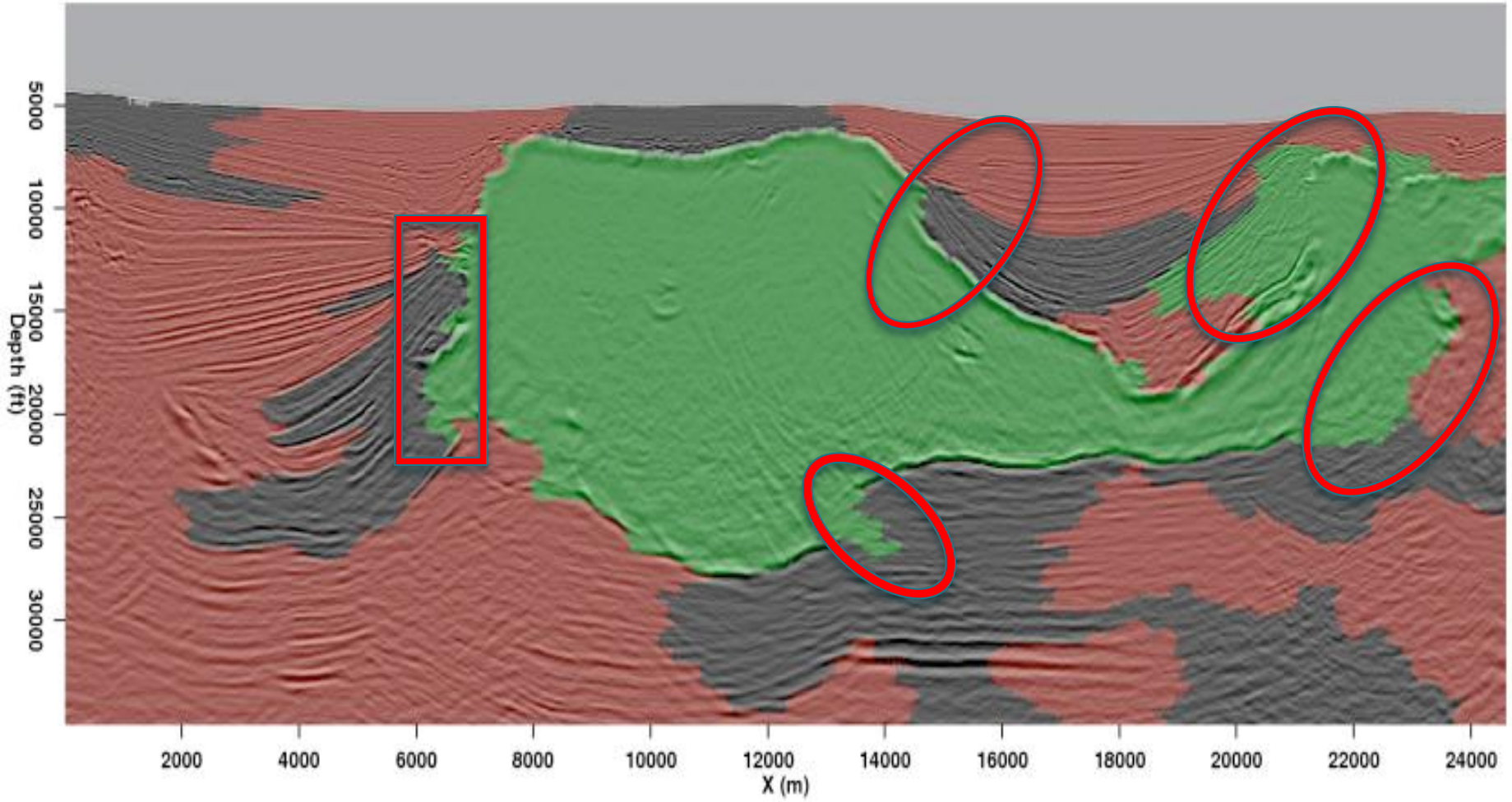
(from BOEM.gov)

Automatic salt body picking

Seismic images are so noisy that it is ***impossible*** to let computer to do this job all on its own

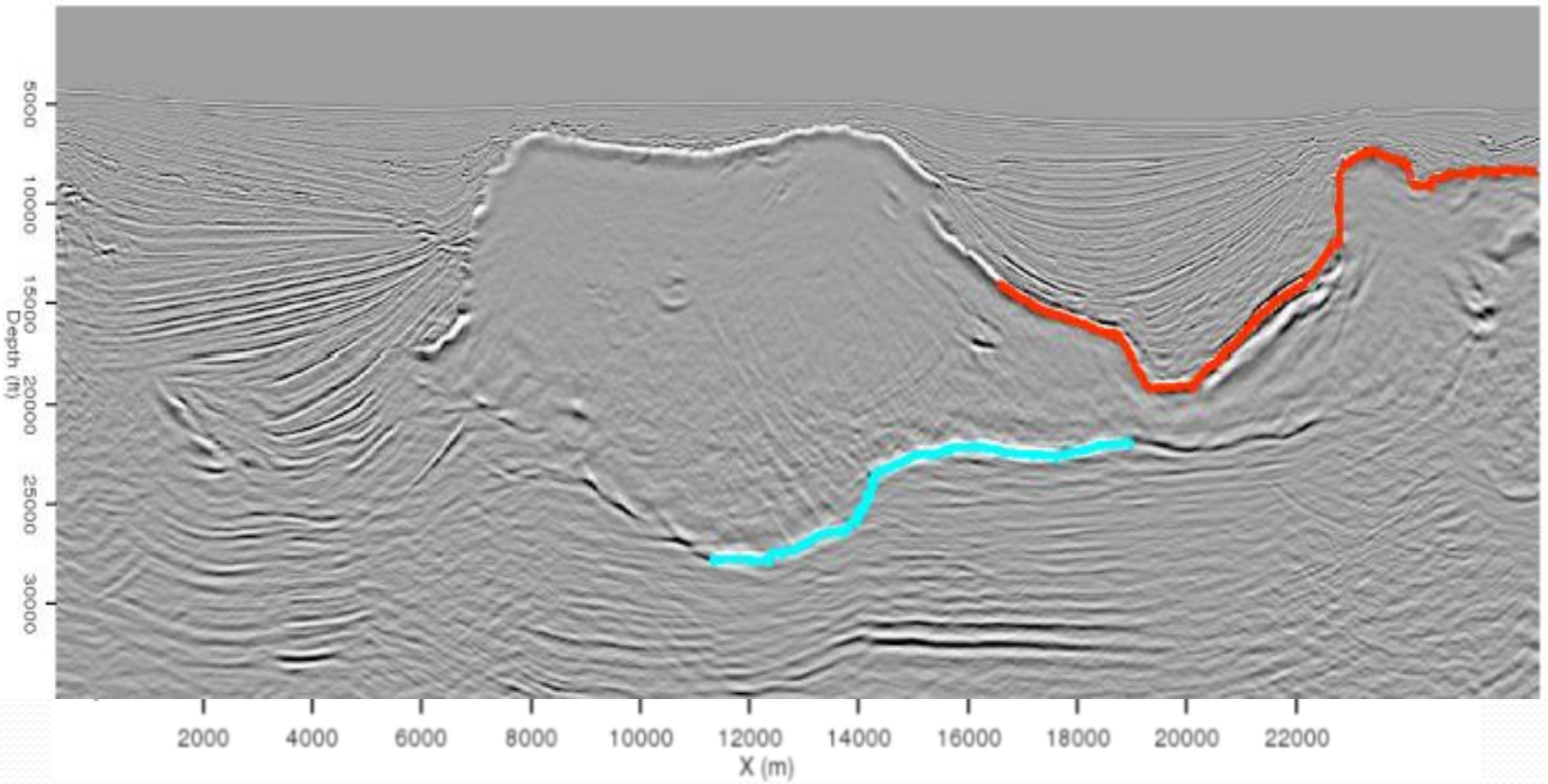


Fully automatic methods are very unlikely



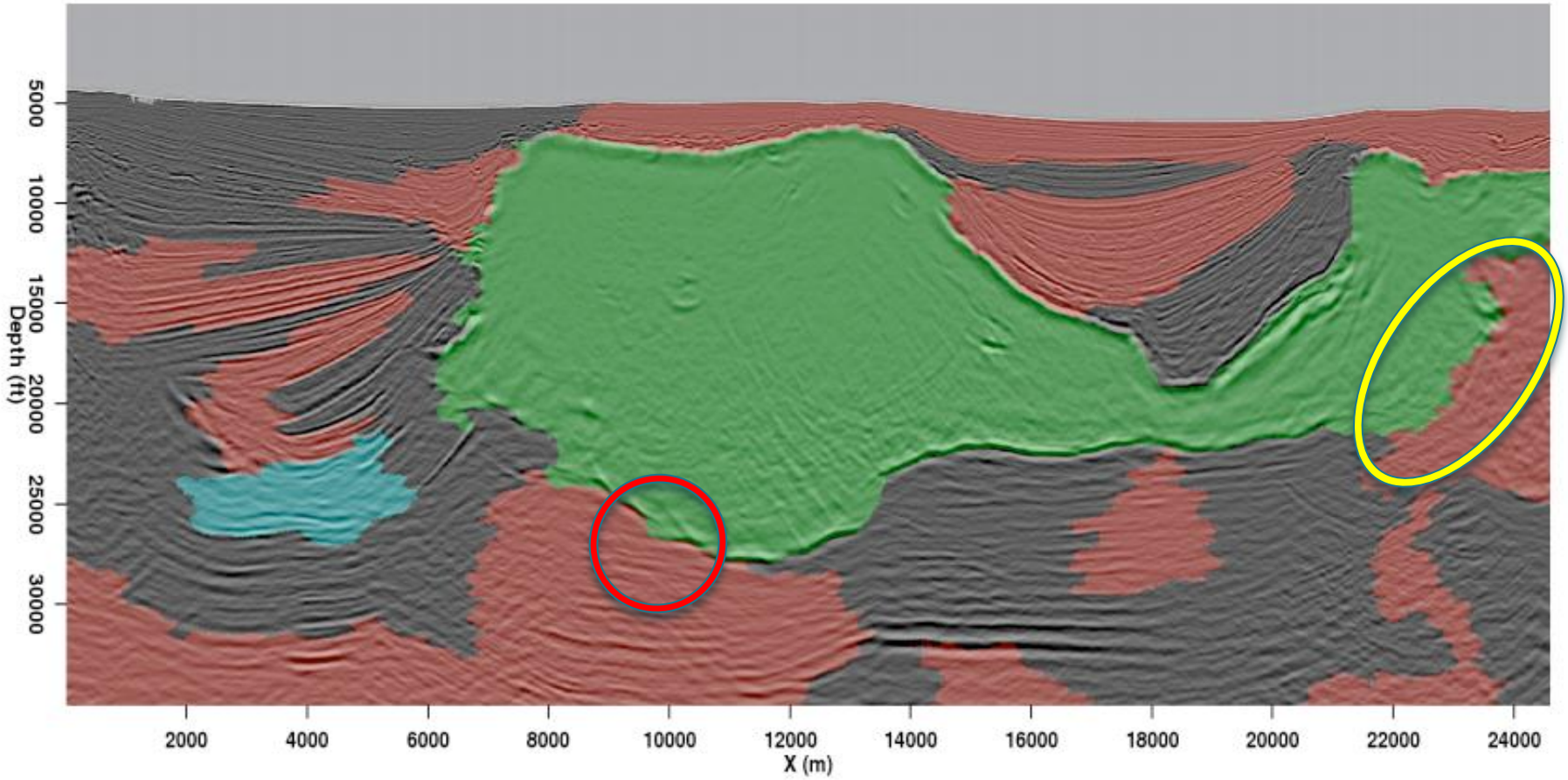
(Halpert,2011)

Human-input is essential



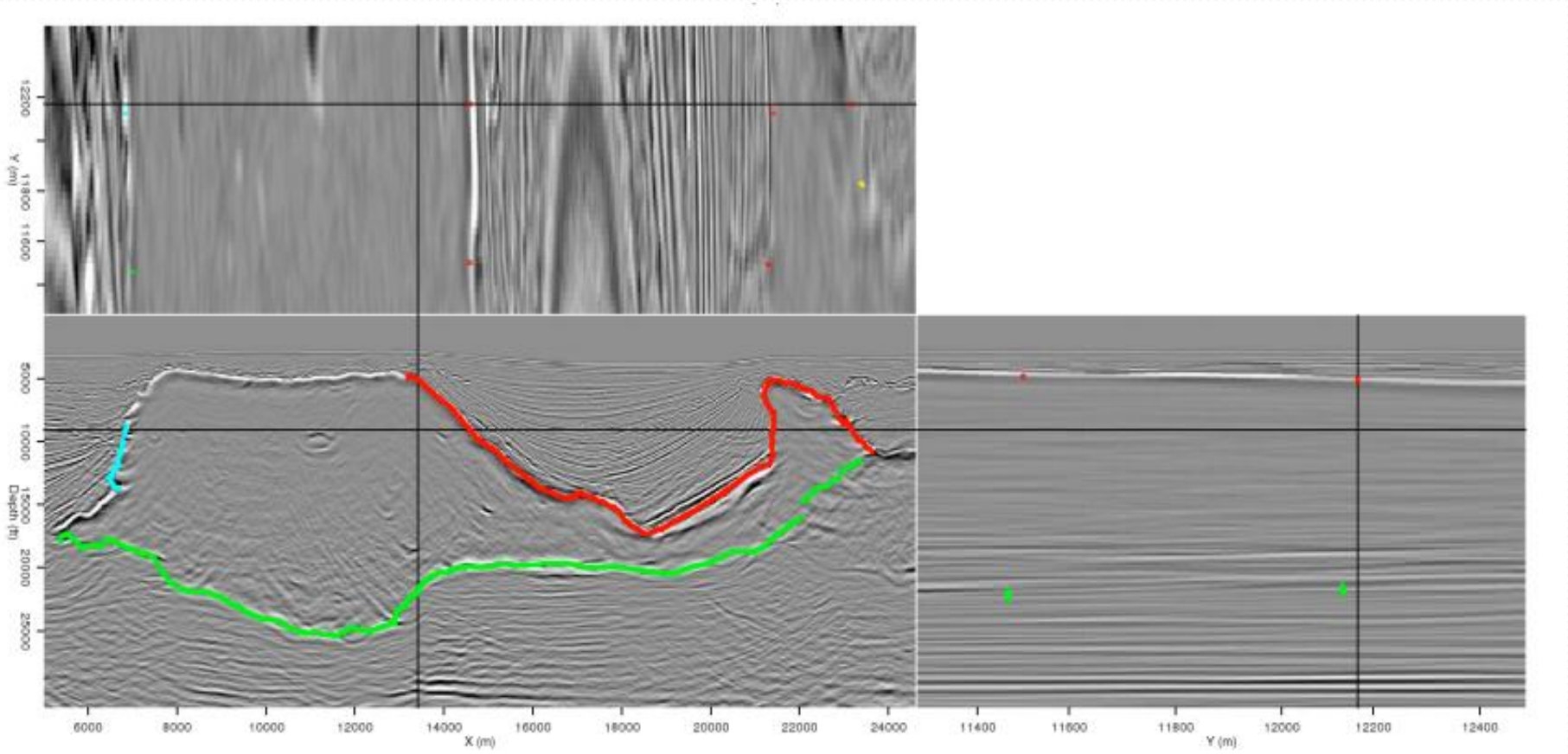
(Halpert,2011)

Improved segmentation after adding human input



(Halpert,2011)

3-D: Curse of dimensionality

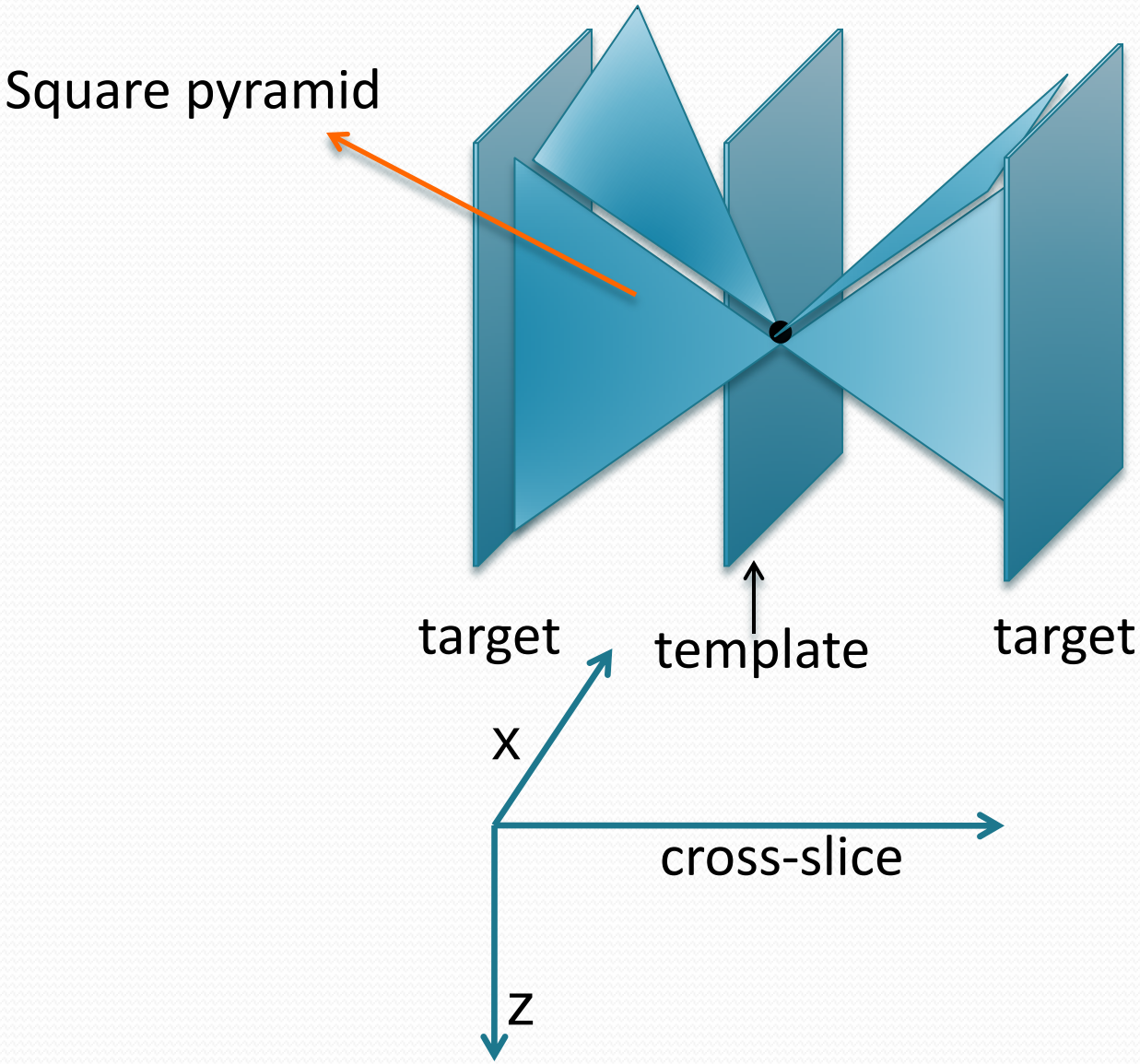


(Halpert,2011)

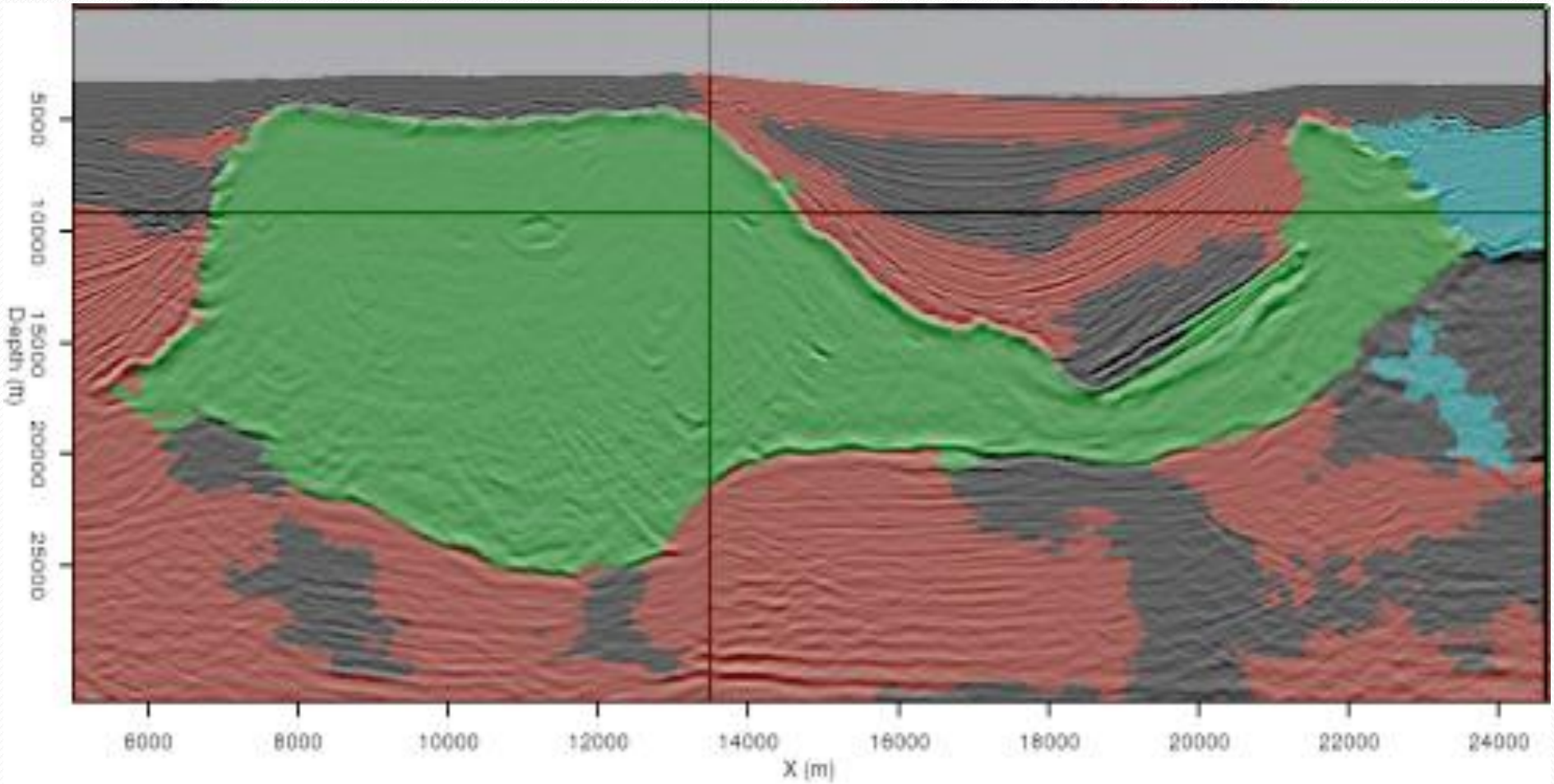
Outline

- Motivation: why do we propose semi-automatic segmentation method?
- Problem: How to make most use of the limited amount of manual interpretation?
- Previous solution: cross-slice smearing
- New solution: boundary deformation
- GOM 3-D seismic image example
- Discussions & conclusion

Quick engineering to propagate manual picks: cross-line smearing

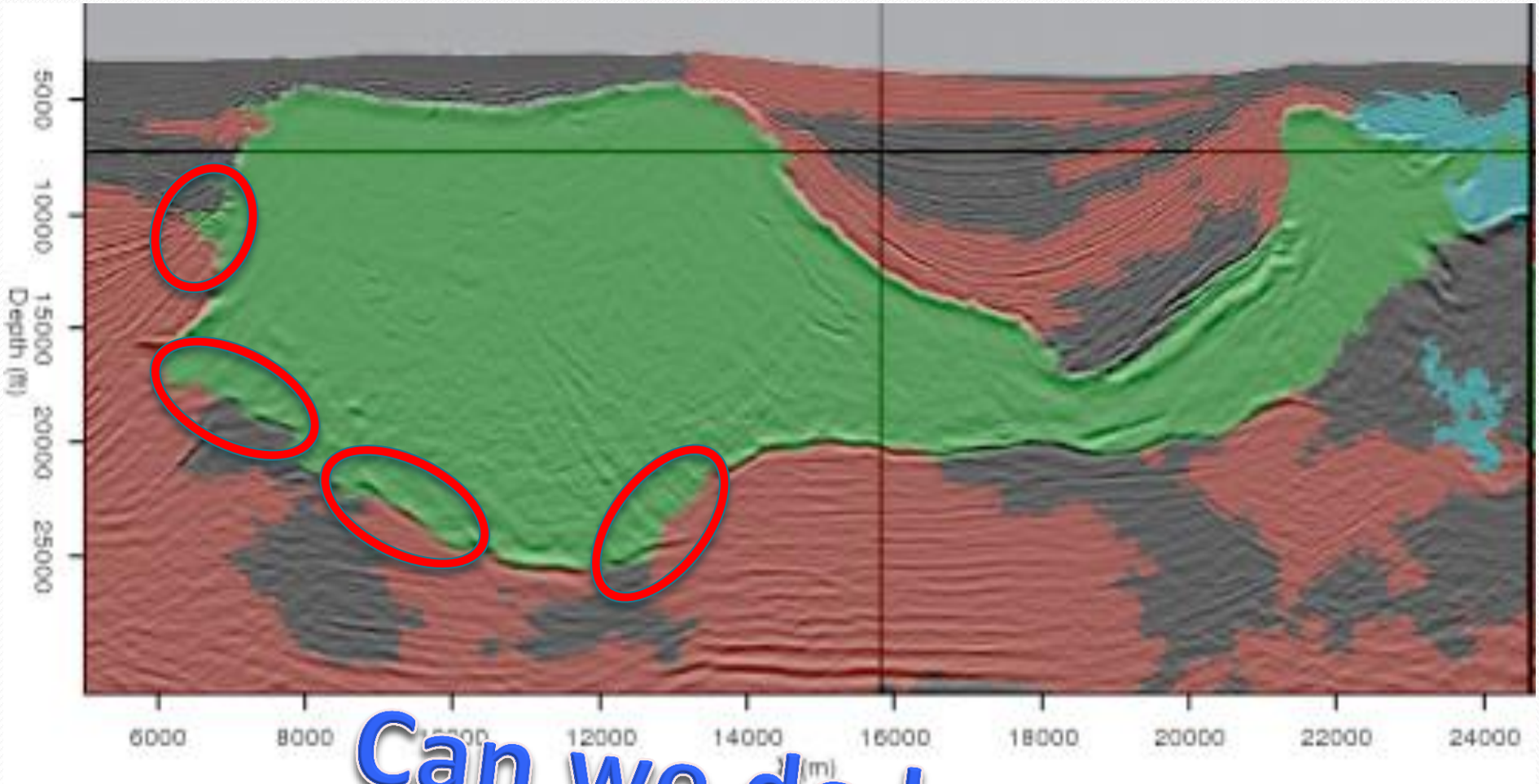


Segmentation on the slice that has picks



(Halpert,2011)

Segmentation 9 slices (270m) away from picks



(Halpert,2011)

Can we do better?

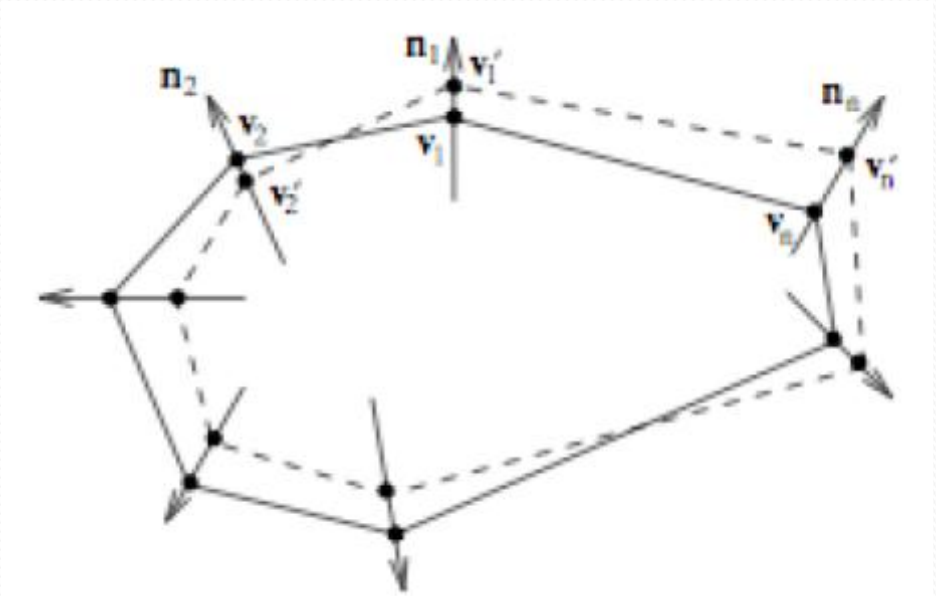
Solve as a boundary deformation problem

- The boundary differences between neighboring slices are generally very small!

- Properly deform the salt boundary known from the *template* slice (which has picks) into the nearby *target* slice (without picks)
- Two criterions (Wang,2001) for the deformation:
  - honor the available boundary information on the target slice
  - preserve the overall shape from the template slice

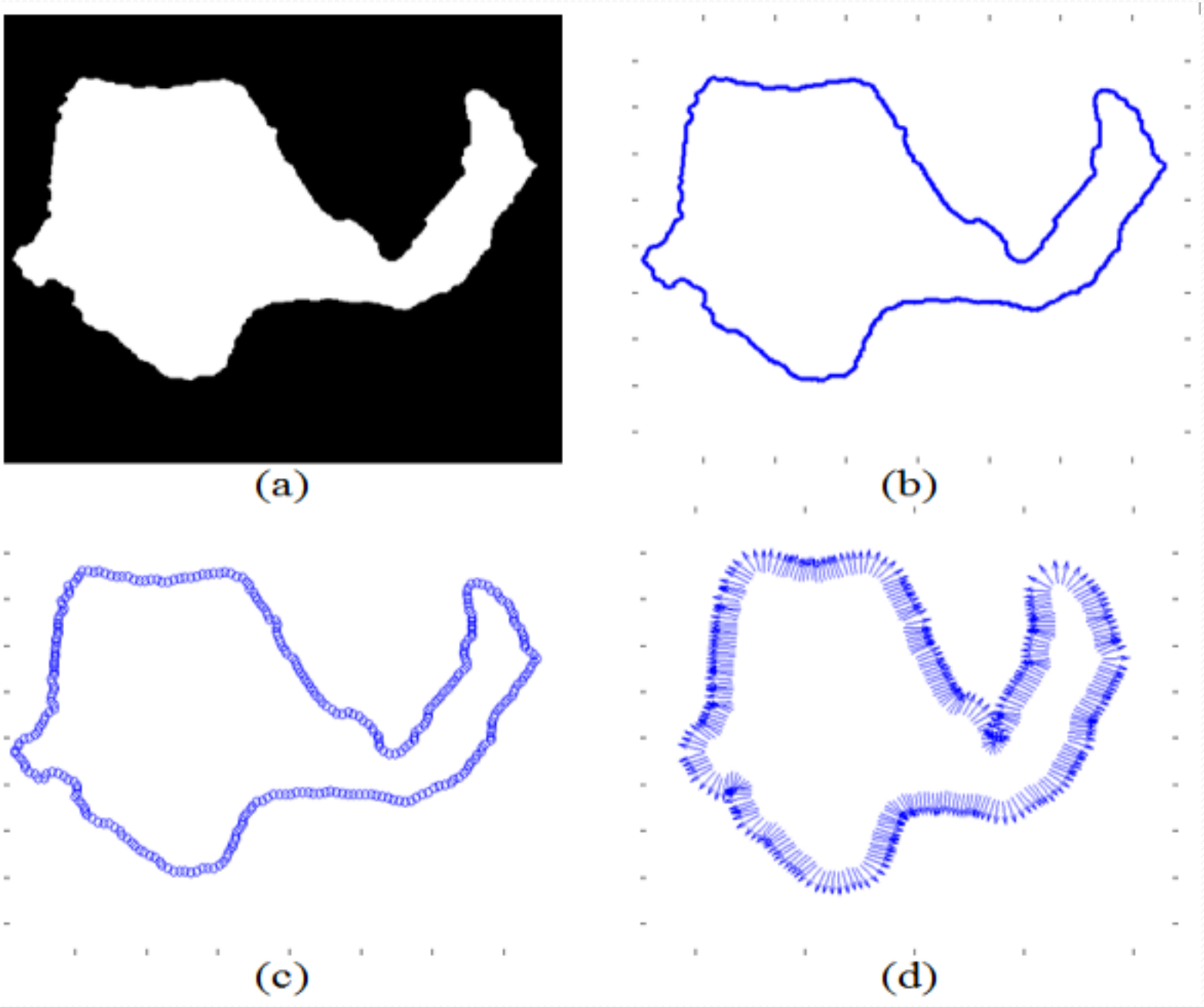
Deformation formulation (1)

- Parameterization
  - represent the contour of the template image (known) using an ordered list of **landmark points**: $V=\{v_1, v_2, \ldots, v_n\}$
  - constrain the landmarks, so that they can deform only along the normal direction



(Wang, 2001)

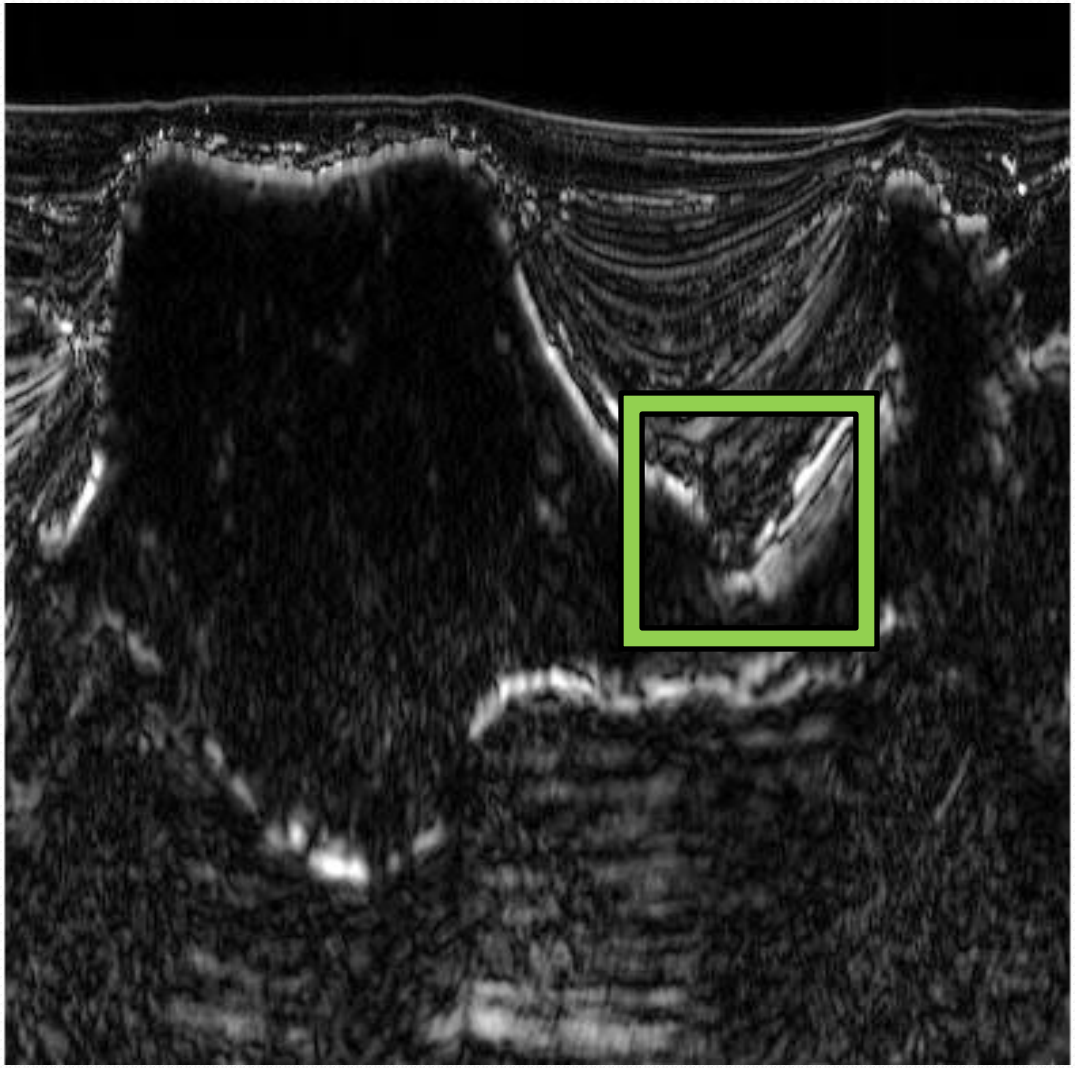
Preprocessing flow



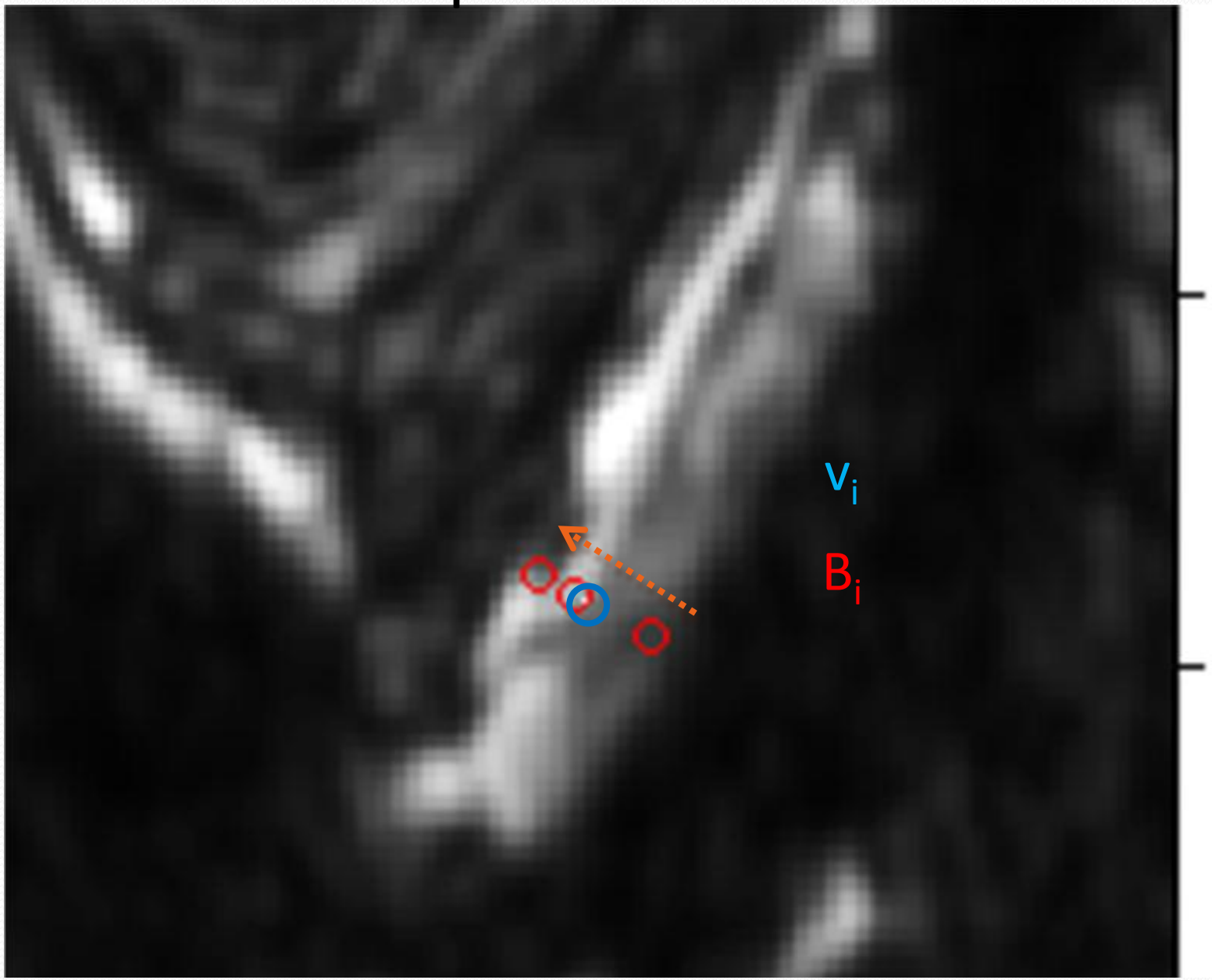
Deformation formulation (2)

- Honor the available boundary information on the target slice
  - For each landmark v_i , the method first identifies a set of **possible corresponding landmark** points $B_i = \{v_i^{(j)}, j=1,2,...,n_i\}$ on the *target* slice, by examining some local features in the target

Use envelope to find potential boundary

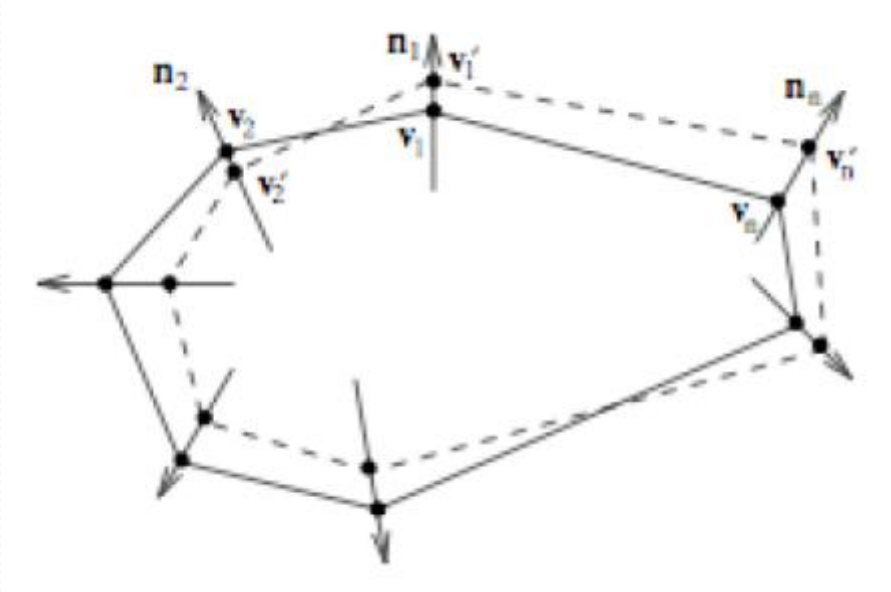


Candidate points found at i=137



Deformation formulation (3)

- Randomly draw each v_i' from the potential corresponding landmarks set B_i , to form set $V' = \{v_1', v_2', \ldots, v_n'\}$ for the target slice
- Deform the prior shape V to match V' while trying to keep the shape characteristics of V



Deformation as an optimization

- Deform the prior shape V to match V' while trying to keep the shape characteristics of V
- Formulated as an optimization problem of finding a transform
  $\mathbf{t}: \ (x, y) \rightarrow (f(x, y), g(x, y)) = (x', y')$,
  such that it minimize

$$\frac{1}{n}\sum_{i=1} Q(v_i', \mathbf{t}(v_i)) + \lambda\phi(\mathbf{t})$$

matching the chosen landmark V'

trade-off weight

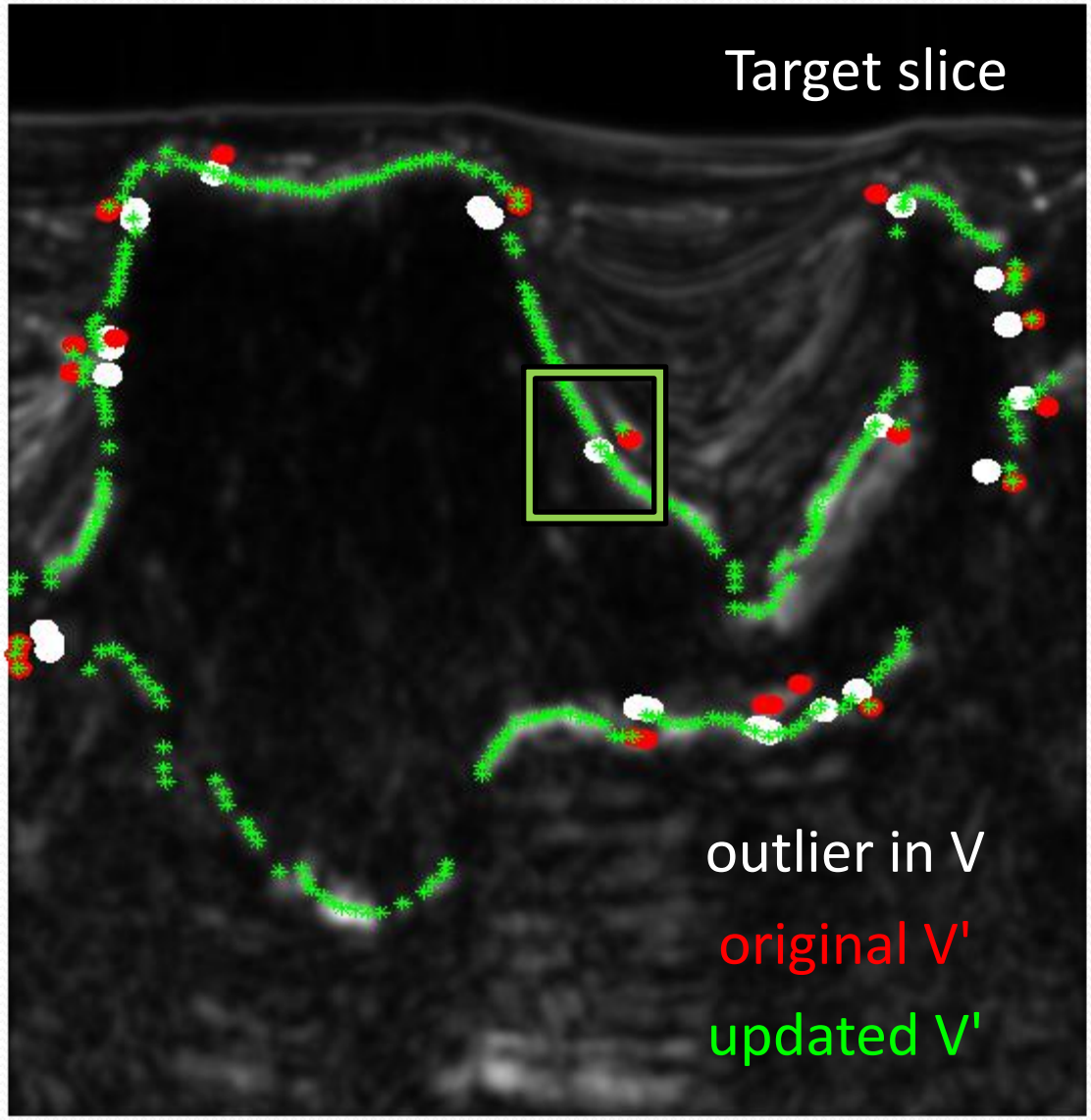
preserving the global shape info from the template image

Run multiple optimizations

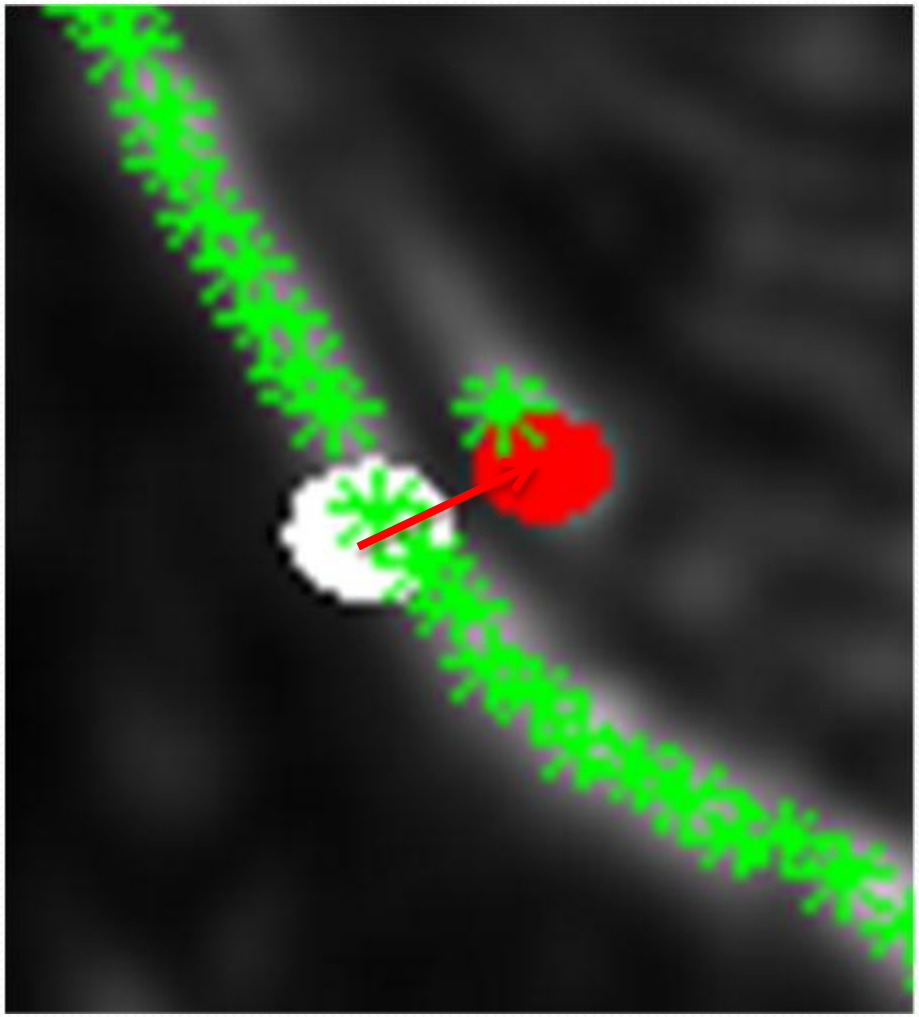
- Iterate to find the optimum V'
  - with an initial V', solve the optimization (can evolve to quadratic programming problem)
  - identify the outliers in the V→V' fitting
  - update V' = {v_1', v_2', …, v_n'} using the available candidates in B_i sets.

- In the end, we will retrieve the best candidate points in V'_{opt} and the optimal mapping t_{opt}

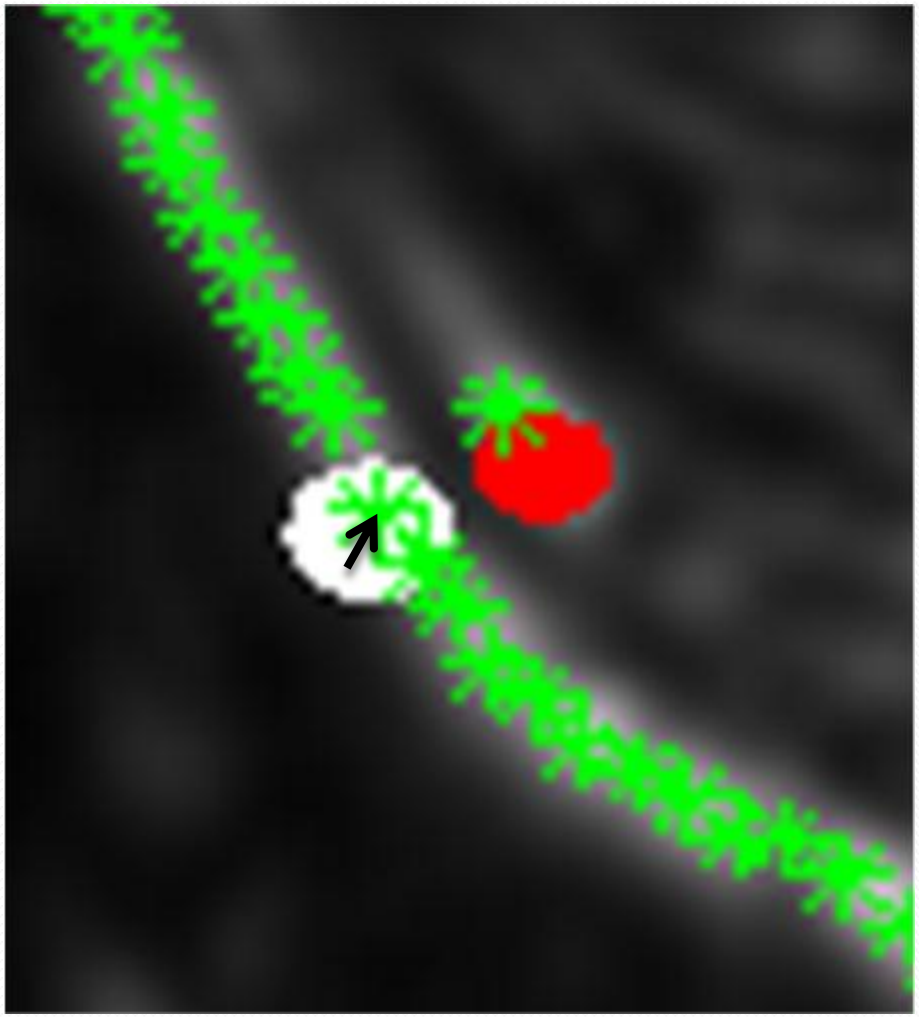
One iteration of updating V'



Before update



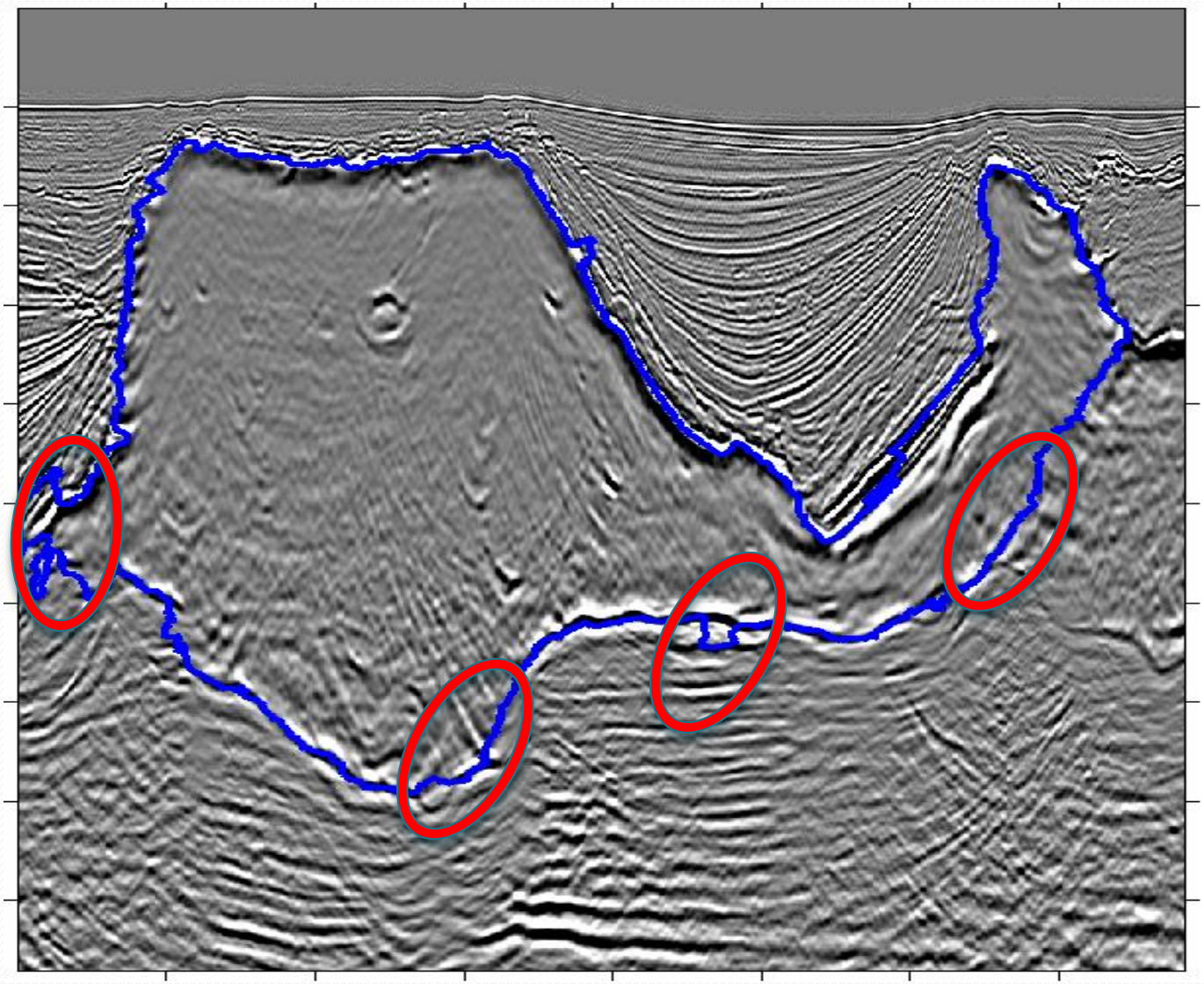
After update



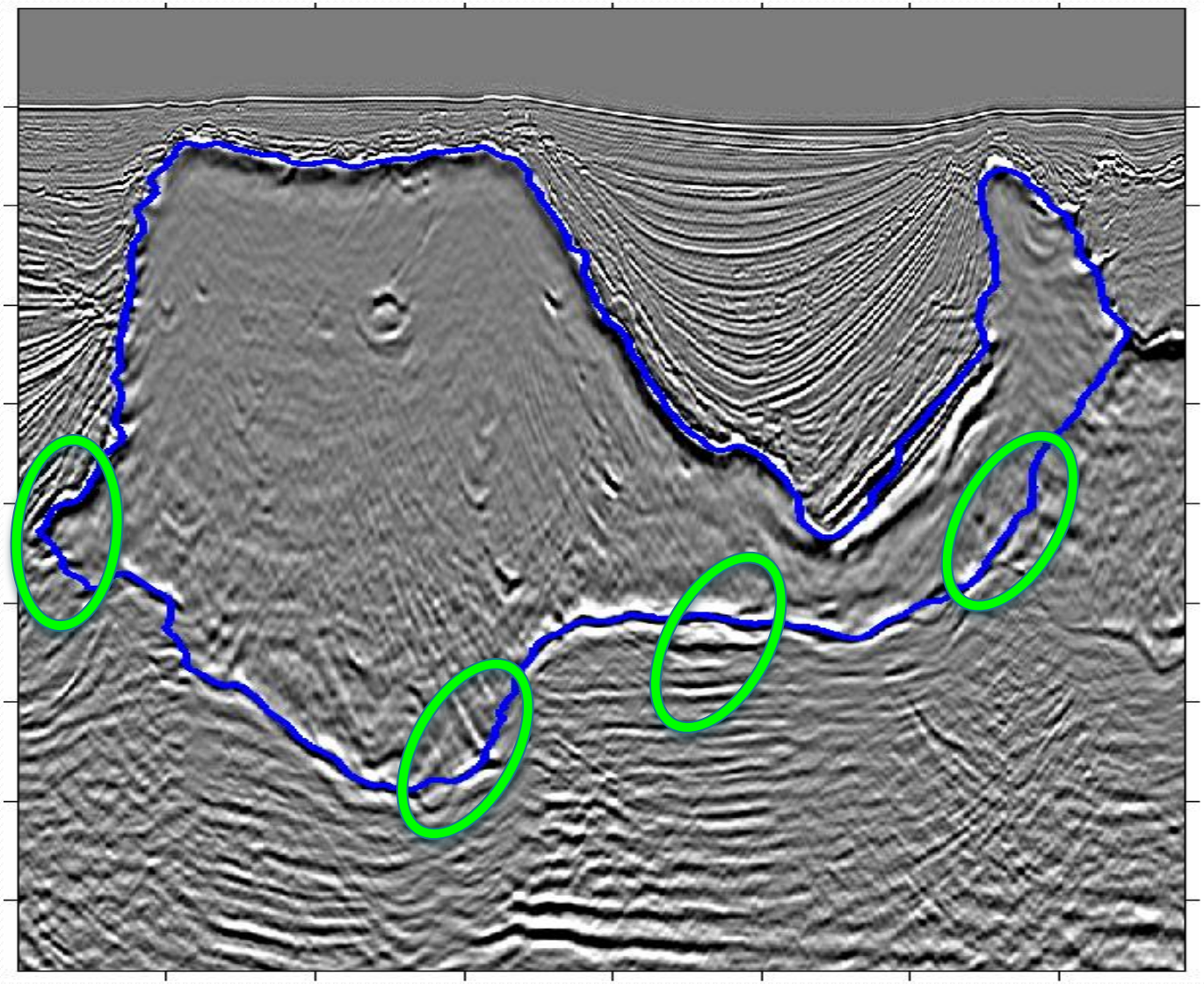
3-D GOM seismic image result

- 12 slices, slice spacing 30 m
- Manual picking on 1st slice
- Deform sequentially from 1st to 12th slice
- Compare old and new method

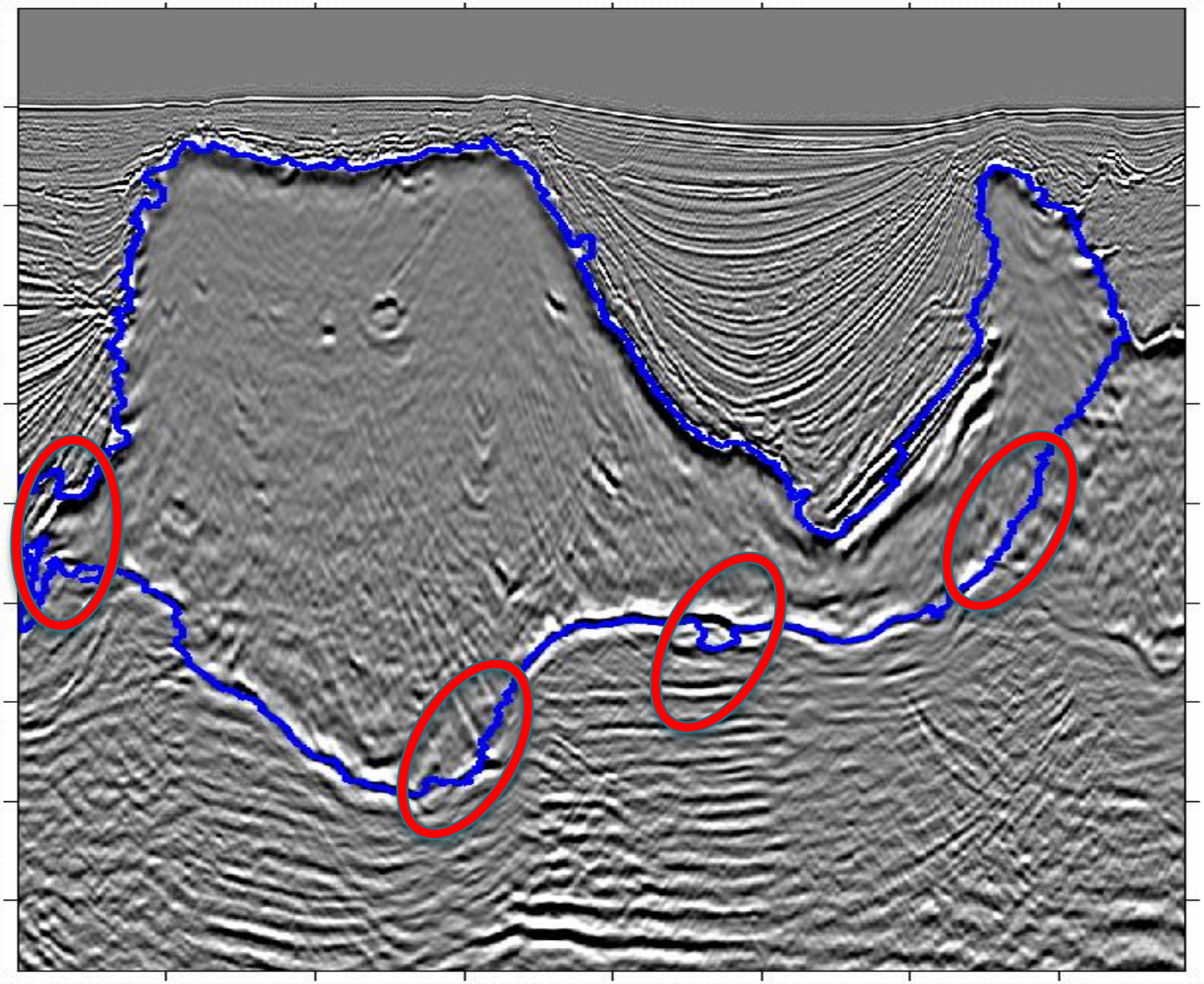
1st slice, cross-slice smearing



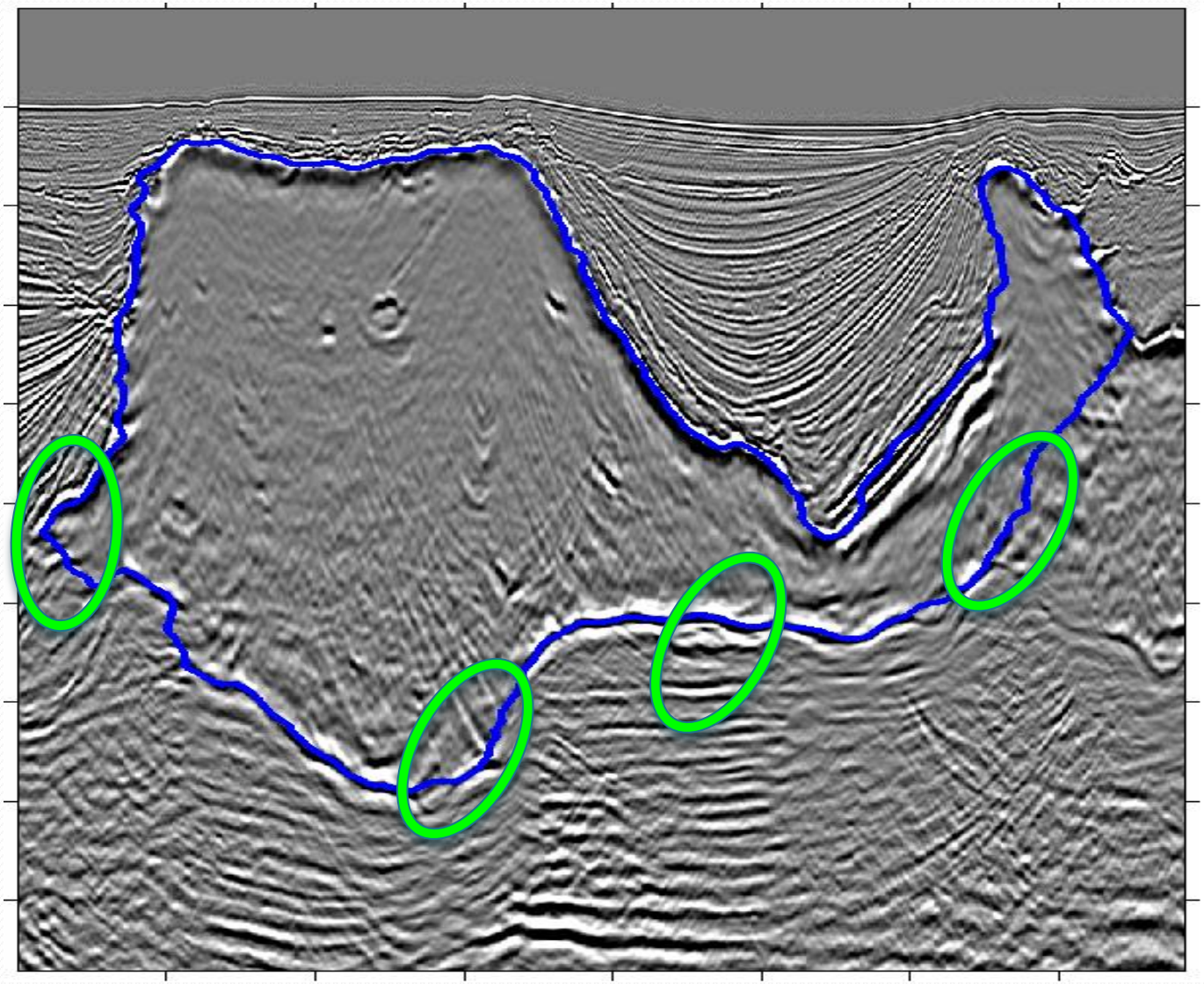
1st slice, deform



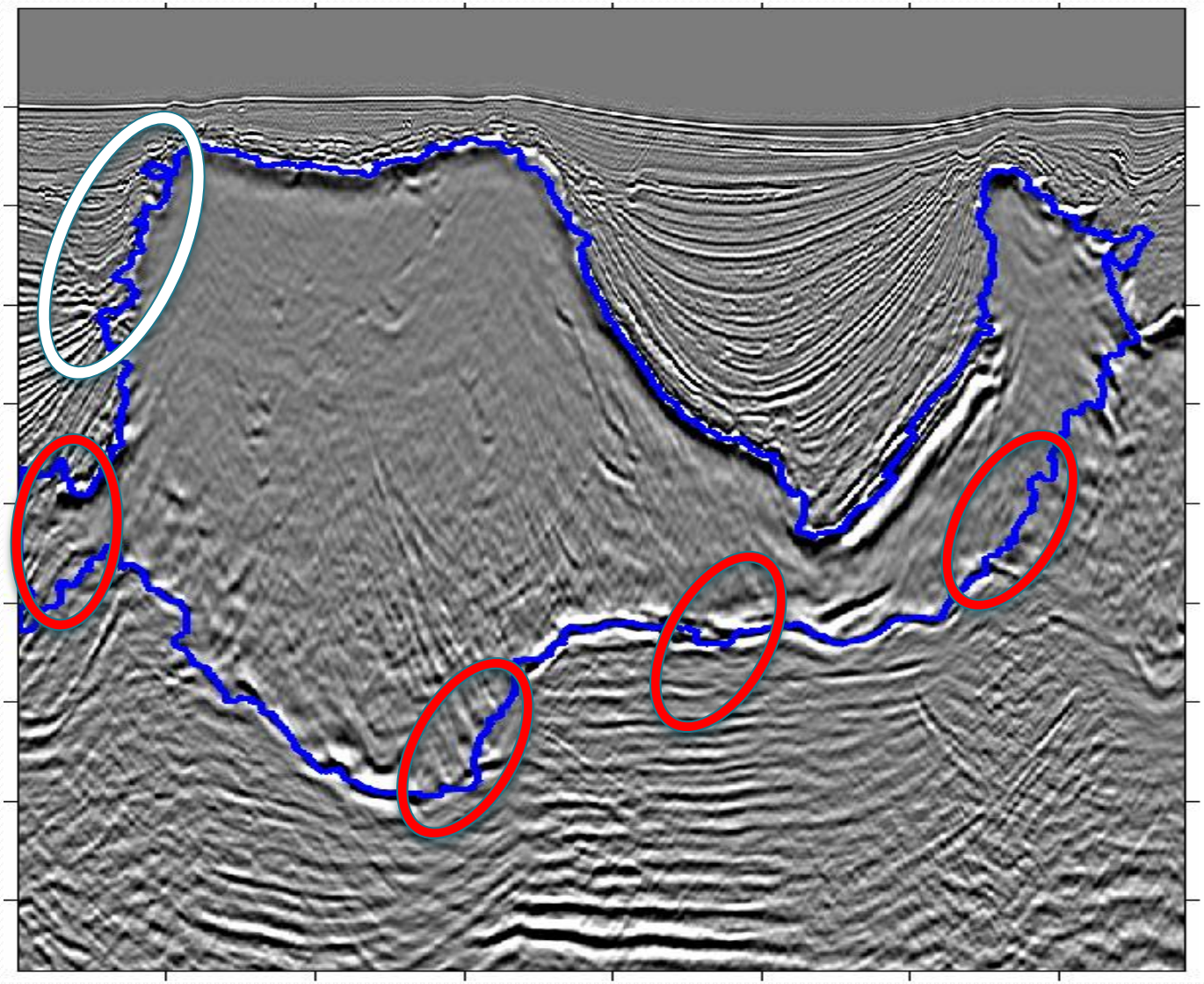
4th slice, cross-slice smearing



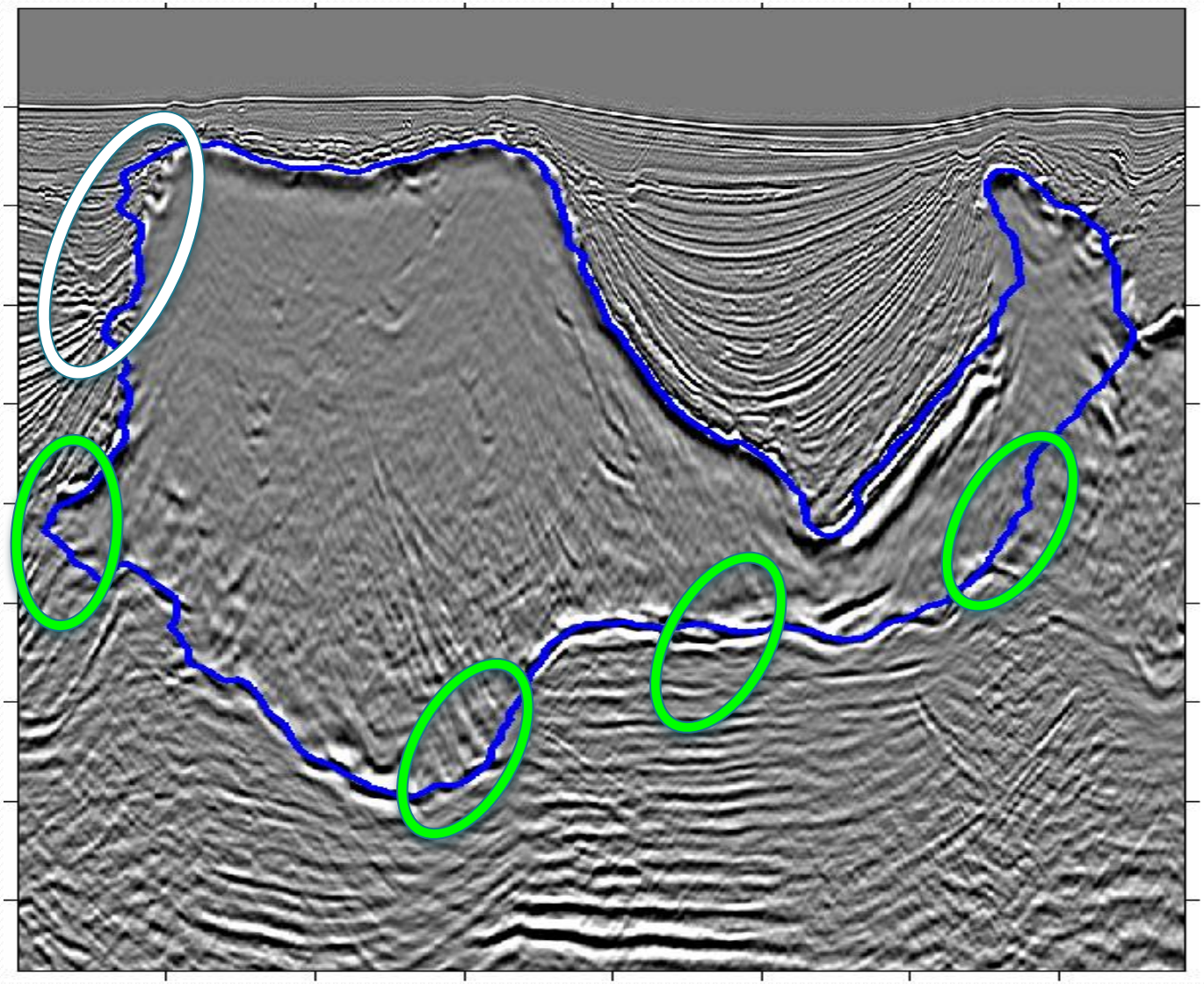
4th slice, deform



12th slice, cross-slice smearing



12^{th} slice, deform



Discussion & Conclusion

- Multiple salt-bodies
  - Extension to multiple contours is straightforward
- Computational cost
  - Every deformation involves solving a few (~10) quadratic programming problems of size n = #landmarks
  - Take <1 min per slice, single thread
  - Memory requirement is low
- Parameter tuning, most importantly, the λ parameter

More application scenarios

- Assist the manual horizon picking process during the tomography iterations.
  - the reflector geometry changes slightly with each velocity update

- Acknowledge
  - WesternGeco
- References

  - Song Wang, Weiyu Zhu and Zhi-Pei Liang, "Shape deformation: SVM regression and application to medical image segmentation", Proceedings. Eighth IEEE International Conference on, vol.2, pp.209-216, ICCV 2001.
  - F. L. Bookstein, "Principal warps: Thin-plate splines and the decomposition of deformations", IEEE Trans. PAMI, 11:567– 585, June 1989.
  - Halpert, A., R. G. Clapp and B. L. Biondi, "Interpreter guidance for automated seismic image segmentation", 74th Annual International Conference and Exhibition, EAGE 2011.
  - Halpert, A., "Interpreter input for seismic image segmentation", SEP report 143, 2011.

How to improve it?

- Define better ways to find candidates in the input images.
- Assign weight to the candidates based on our confidence of the pick.
- Gradient based optimization method (e.g. hybrid norm solver) so that we don't need to do Quadratic Programming multiple times.