Shale Diapirism and Associated Folding History in the South Caspian Basin (Offshore Azerbaijan)*

J. I. Soto[1], I. Santos-Betancor[1], I. Sánchez Borrego[2], and C. E. Macellari[3]

Search and Discovery Article #30162 (2011)
Posted May 31, 2011

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Houston, Texas, April 10-13, 2011

[1]Inst. Andaluz Ciencias de la Tierra (CSIC-UGR), Granada University, Granada, Spain (jsoto@ugr.es)
[2]Department of Statistics, Granada University, Granada, Spain
[3]Repsol Exploración S.A., Madrid, Spain

Abstract

The Caspian Sea is a Neogene basin associated with the Alpine-Himalayan collision and has one of the major sedimentary accumulations in the world. The South Caspian Basin, in particular, comprises a thick (~ 10 km), fluvio-deltaic sequence, the Productive Series, deposited during the late Miocene to middle Pliocene (~6-3 Ma) over a rapidly subsiding crust of probable oceanic nature. The uppermost sedimentary cover is affected by numerous detachment folds cored by overpressured, organic-rich muds derived from the marine source rock of the Maykop Series; of Oligocene to early Miocene age. The tectonic evolution of the South Caspian Basin triggered mud migration of the Maykop Series trapping oil and gas in anticlines structures. Major reservoirs are concentrated there in the Productive Series and the stratigraphic seal is a late Pliocene unconformity (~3 Ma).

Our study focused on the geometrical analysis of the folding history in offshore Azerbaijan. We use a post-stack 3D seismic cube tied with data from two exploration wells. The overall geometry of the Productive Series reflects low-dipping sequences of different delta systems propagating basinward, and sedimentary thickness is approximately constant. Fold geometries evolve along strike from symmetrical, gentle anticlines, to close, box-like folds that can host double-vergence reverse faults. Anticline culmination coincides commonly with an hour-glass-like mud diapir, where mud ascent and extrusion in the upper tear created vertical welds.

Folding occurred simultaneously with mud diapir perforation and extrusion, along with tilting and differential subsidence toward basin centre, whilst shortening rates vary along fold axis. Maximum shortening estimates are inferred in regions pierced by the overpressured mud, and folding structures indicate a single, low-dipping detachment level at 9.5-11 km depth. A first major folding pulse occurred during the middle Pliocene (~3.5-3.1 Ma), toward the end of the deposition of the Upper Productive Series. Folding rates decreased afterwards during the late Pliocene, although a second, syn-growth folding episode occurred at ~1.5-1 Ma.

We also implement the algorithms to analyze in 3D this detachment folding-type that departs from the classic examples because punctuated

deformation is accompanied by progressive tilting and differential subsidence between fold flanks.

References

Abreu, V., and D. Nummedal, 2007, Miocene to quaternary sequence stratigraphy of the south and central caspian basins, *in* P.O. Yilmaz and G.H. Isaksen, (eds.), Oil and Gas in the Greater Caspian Area: AAPG Studies in Geology, v. 55, p. 65-86.

Berberian, M., 1983, The southern Caspian; a compressional depression floored by a trapped, modified oceanic crust: Canadian Journal of Earth Sciences, v. 20/2, p. 163-183.

Epard, J-L., and R.H. Groshong, Jr., 1993, Excess area and depth to detachment: AAPG Bulletin, v. 77/8, p. 1291-1302.

Gonzalez-Mieres, R., and J. Suppe, 2006, Relief and shortening in detachment folds: Journal of Structural Geology, v. 28/10, p. 1785-1807.

Inan, S., M.N. Yalcin, I.S. Guliev, K. Kuliev, and A.A. Feizullayev, 1997, Deep petroleum occurrences in the Lower Kura depression, South Caspian Basin, Azerbaijan: an organic chemical and basin modeling study: Marine and Petroleum Geology, v. 14/7-8, 731-762.

Jones, R.W., and M.D. Simmons, 1996, A review of the stratigraphy of eastern paratethys (oligocene-holocene): Bulletin of the Natural History Museum of London, v. 52/1, p. 25-49.

Krijgsman, W., M. Stoica, I. Vasiliev, and V.V. Popov, 2010, Rise and fall of the Paratethys Sea during the Messinian Salinity Crisis: Earth and Planetary Science Letters, v. 290/1-2, p. 183-191.

Miller, K.G., M.A. Kominz, J.V. Browning, J.D. Wright, G.S. Mountain, M.E. Katz, P.J. Sugarman, B.S. Cramer, N. Christie-Blick, and S.F. Pekar, 2005, The Phanerozoic record of global sea-level change: Science, v. 310/5752, p. 1293-1298.

Poblet, J., M. Bulnes, K.R. McClay, and S. Hardy, 2004, Plots of crestal structural relief and fold area versus shortening; a graphical technique to unravel the kinematics of thrust-related folds: AAPG Memoir, v. 82, p. 372-399.

Shale Diapirism and associated Folding History in the South Caspian Basin (Offshore Azerbaijan)

J. I. Soto[(1)], I. Santos-Betancor[(1)]
I. Sánchez Borrego[(2)] and C. E. Macellari[(3)]

(1) Inst. Andaluz Ciencias de la Tierra, Granada University (Spain) - jsoto@ugr.es
(2) Depart. Statistics, Granada University (Spain)
(3) Repsol Exploracion S.A., Madrid (Spain)

Contribution project PetroShale (TRA2009_0205)

Universidad de Granada

REPSOL

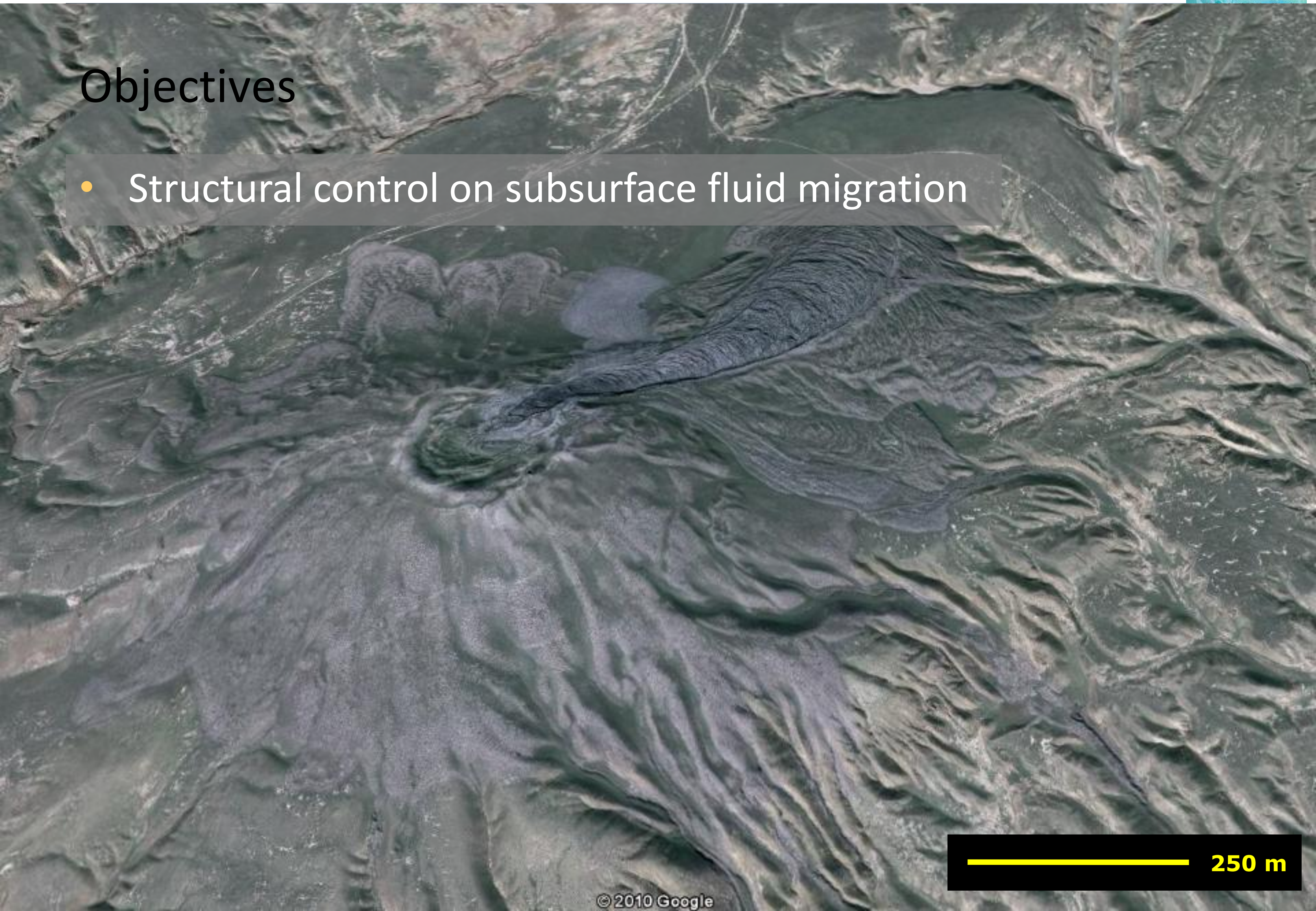
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

Objectives

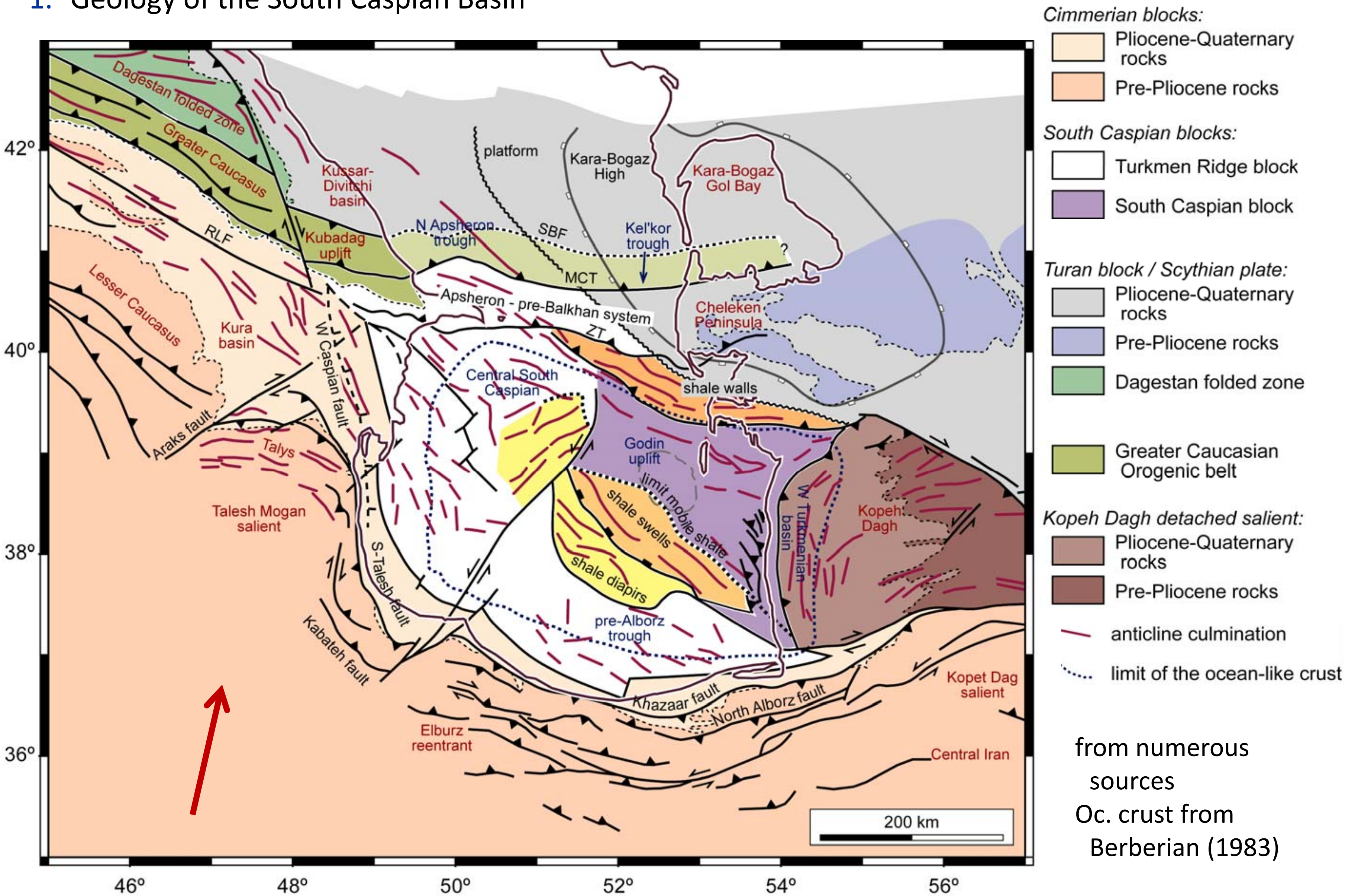
- Characterize in 3D the fold shape
- Reconstruct the *xy-t* evolution of the folding history (shortening magnitude and rate)
- Infer-relationships between folding and mud-diapirism

Objectives

- Structural control on subsurface fluid migration



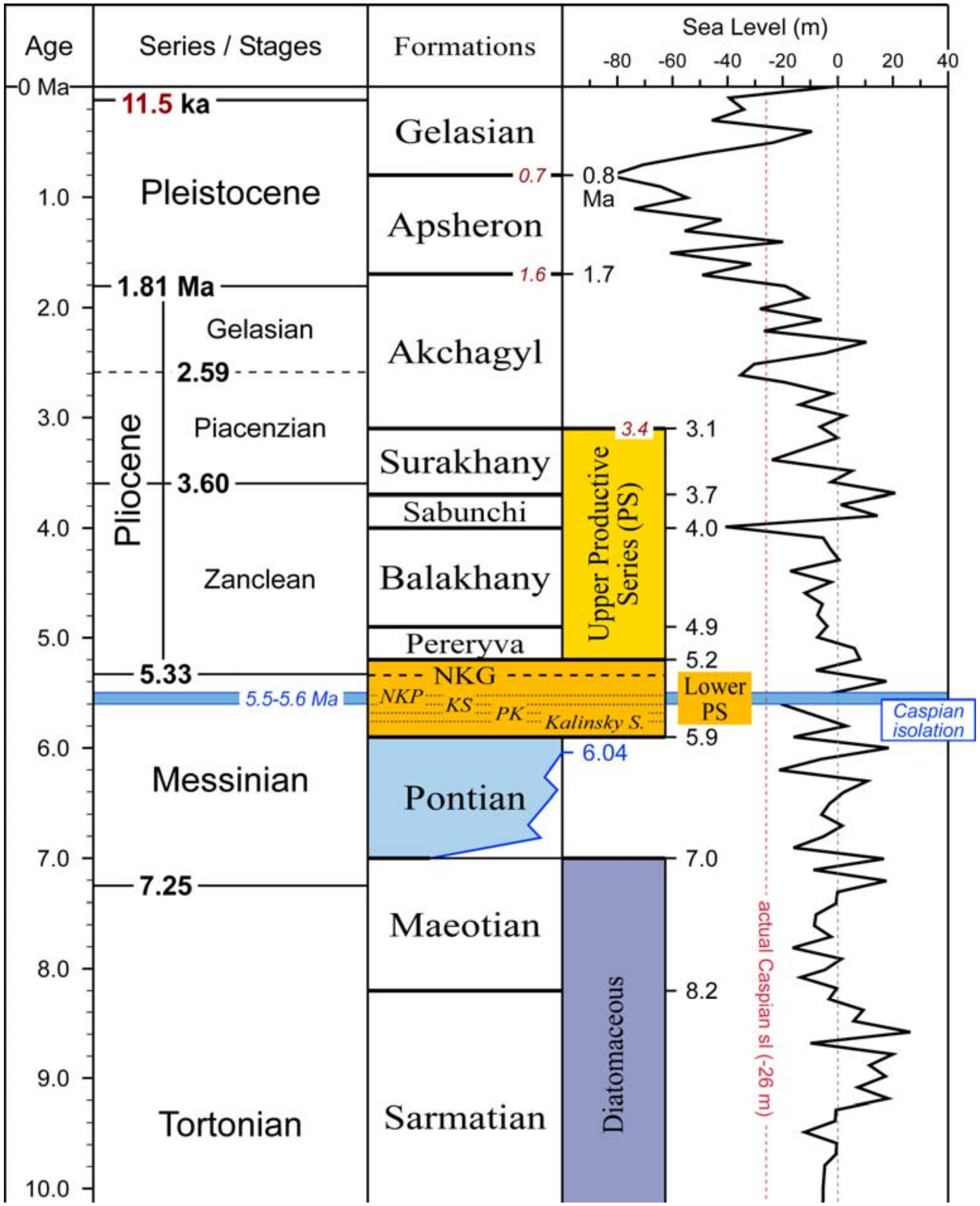
1. Geology of the South Caspian Basin



from numerous sources

Oc. crust from Berberian (1983)

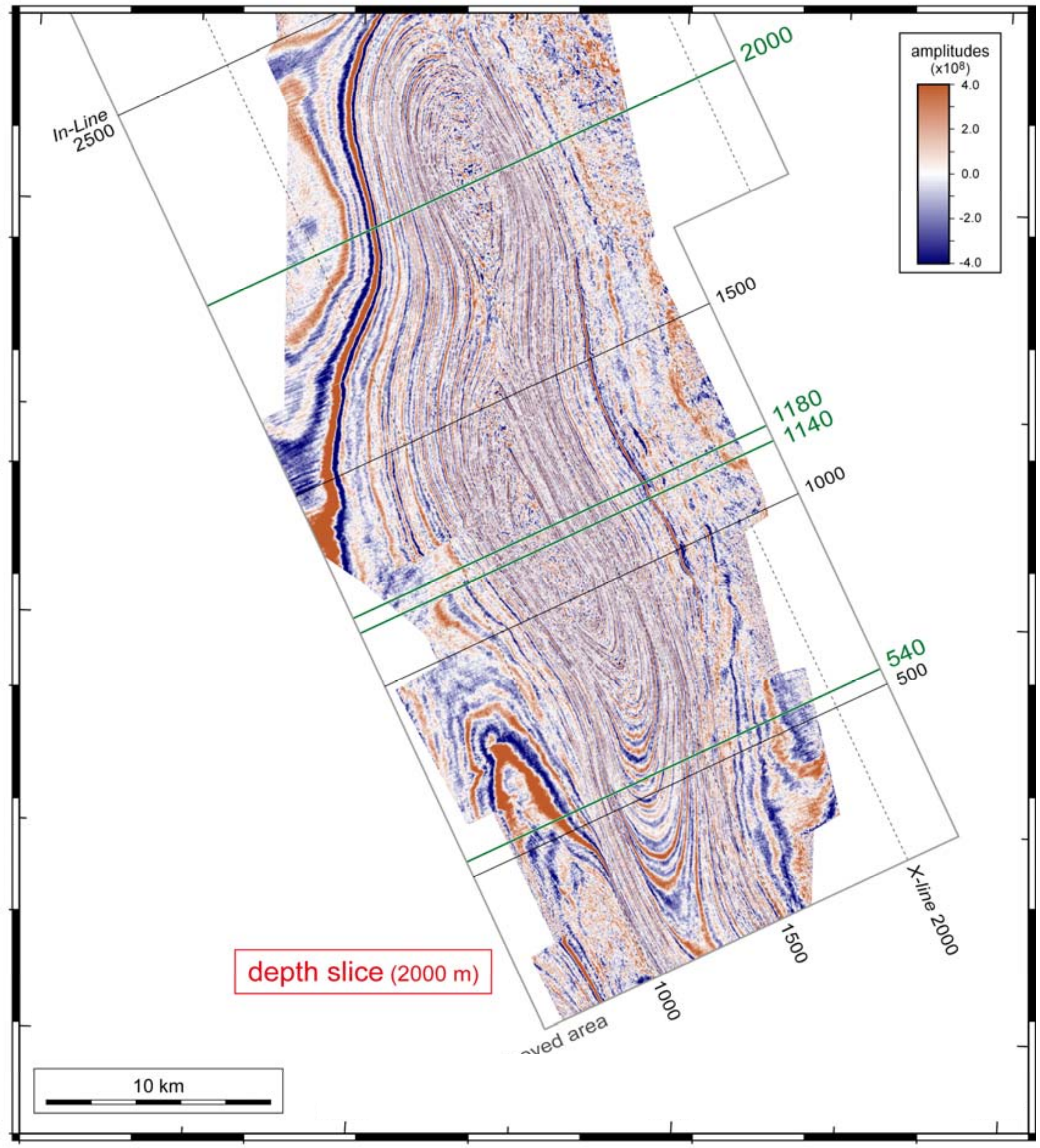
1. Geology of the South Caspian Basin



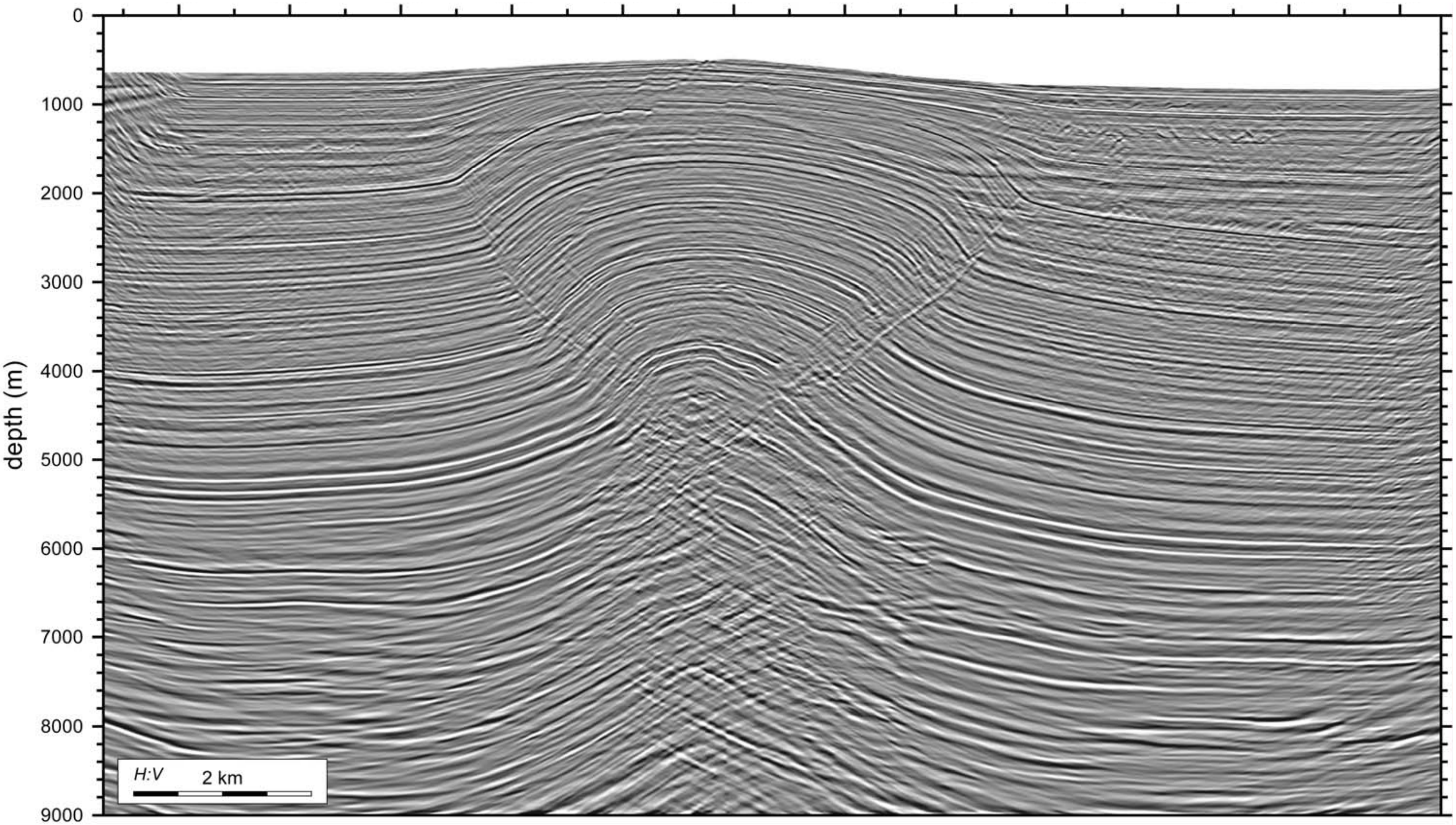
Abreu and Nummedal (2007)
Inan et al. (1997)
Jones and Simmons (1996)

Krijgsman et al. (2010)
Miller et al. (2005)

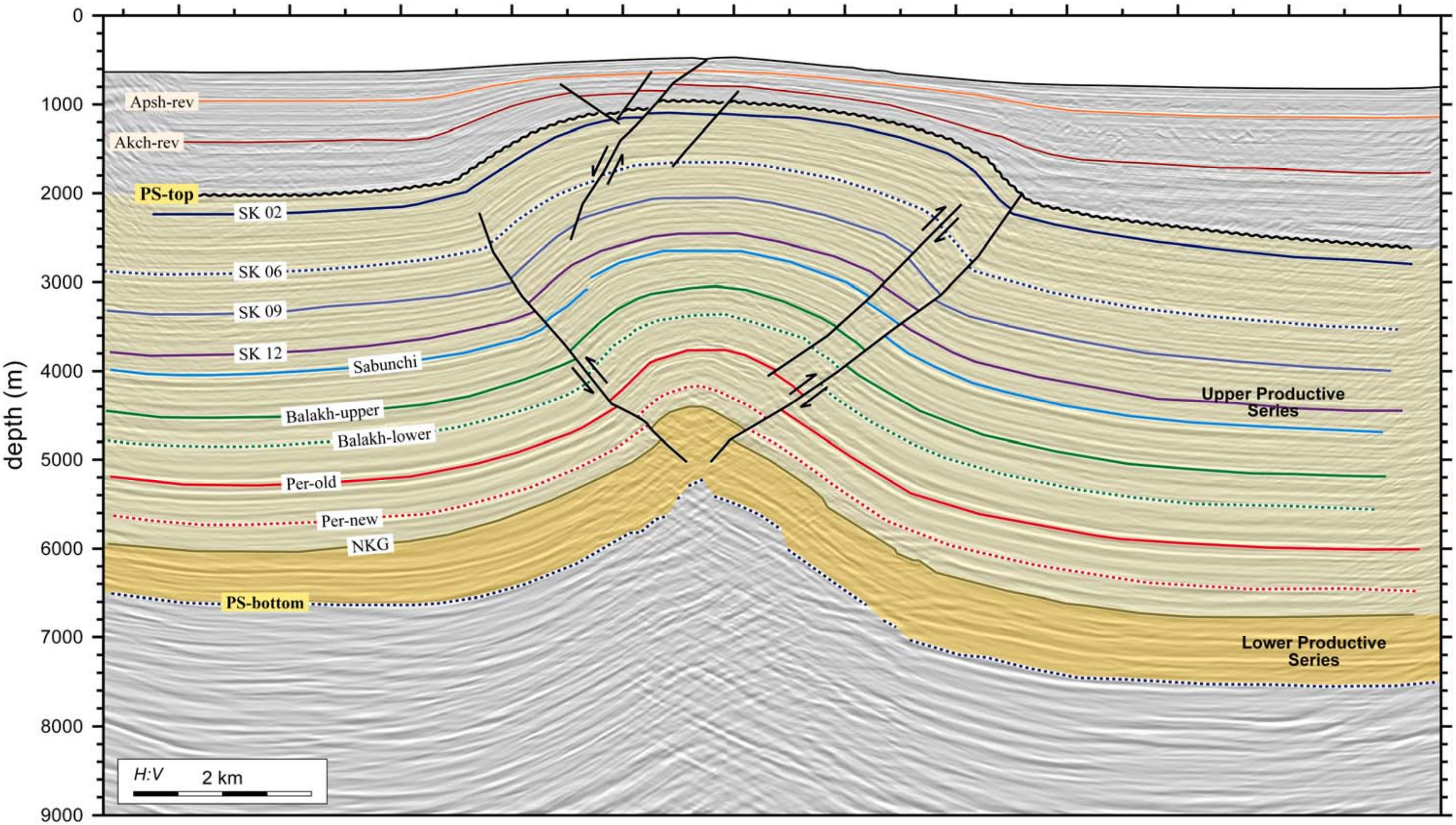
2. Structure


amplitudes
(x10⁸)
4.0
2.0
0.0
-2.0
-4.0
In-Line
2500
2000
1500
1180
1140
1000
540
500
X-line 2000
1500
1000
depth slice (2000 m)
10 km

2. Structure

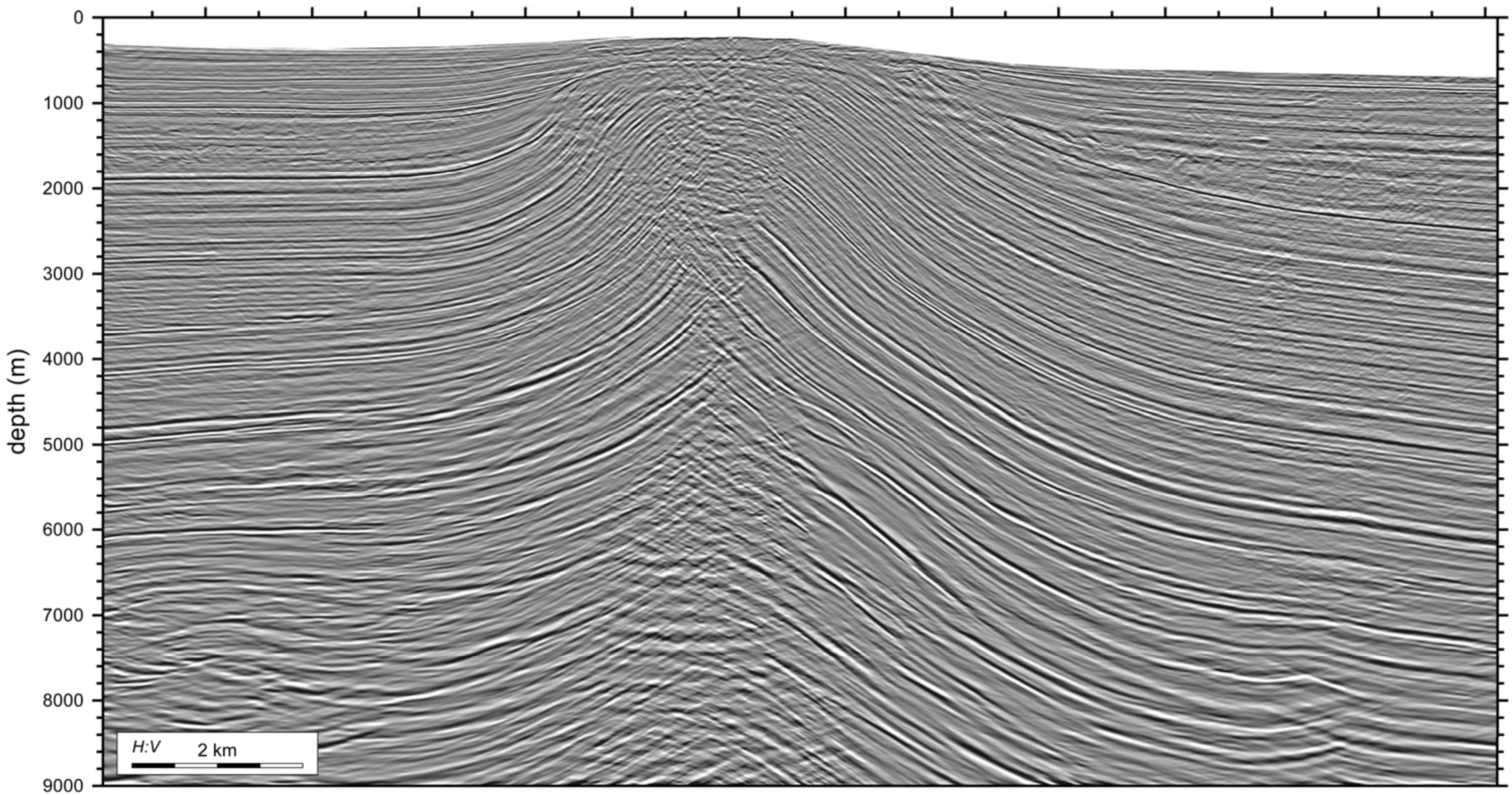


2. Structure



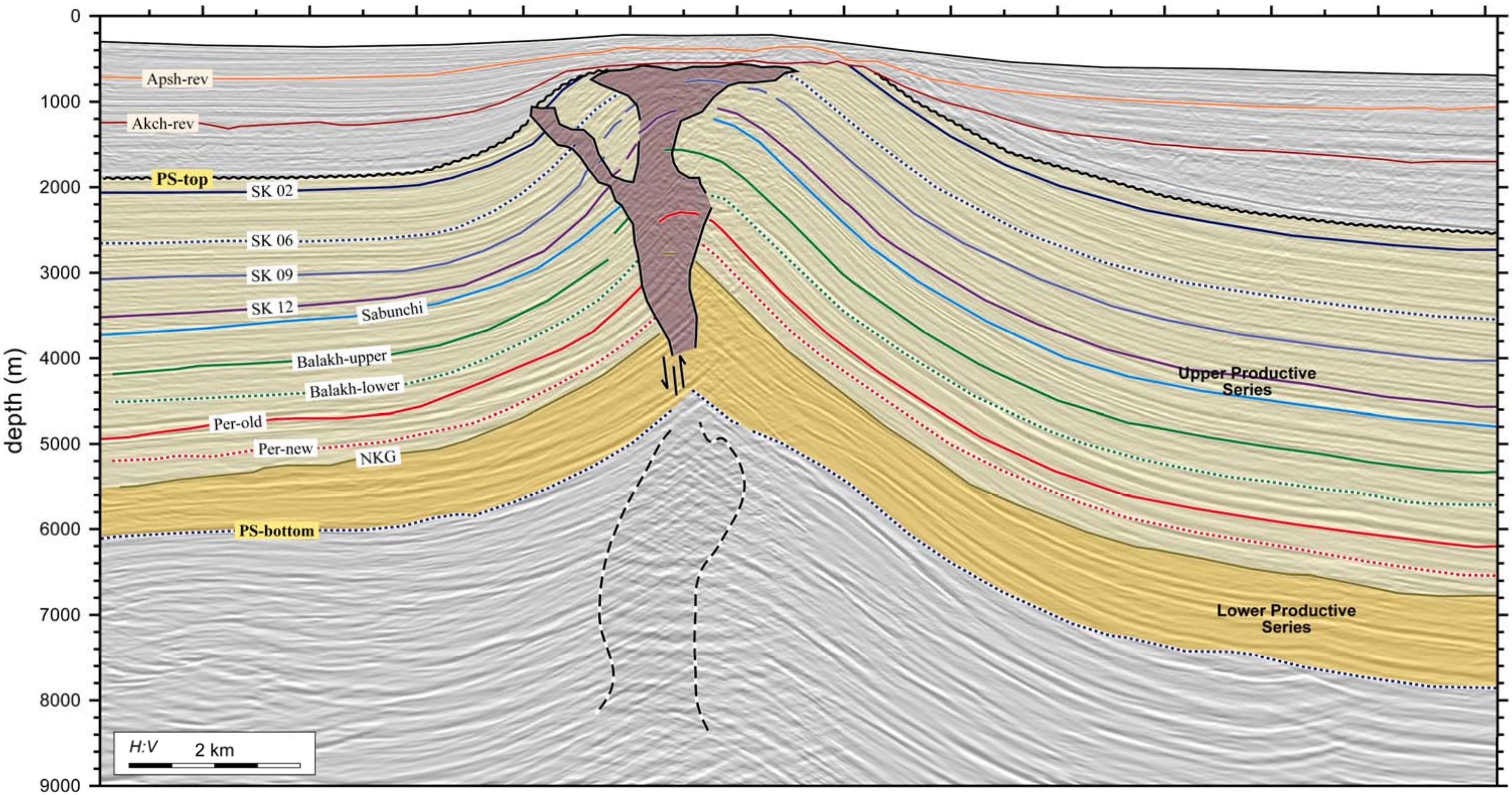
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
depth (m)
Apsh-rev
Akch-rev
PS-top
SK 02
SK 06
SK 09
SK 12
Sabunchi
Balakh-upper
Balakh-lower
Per-old
Per-new
NKG
PS-bottom
Upper Productive Series
Lower Productive Series
H:V
2 km

2. Structure

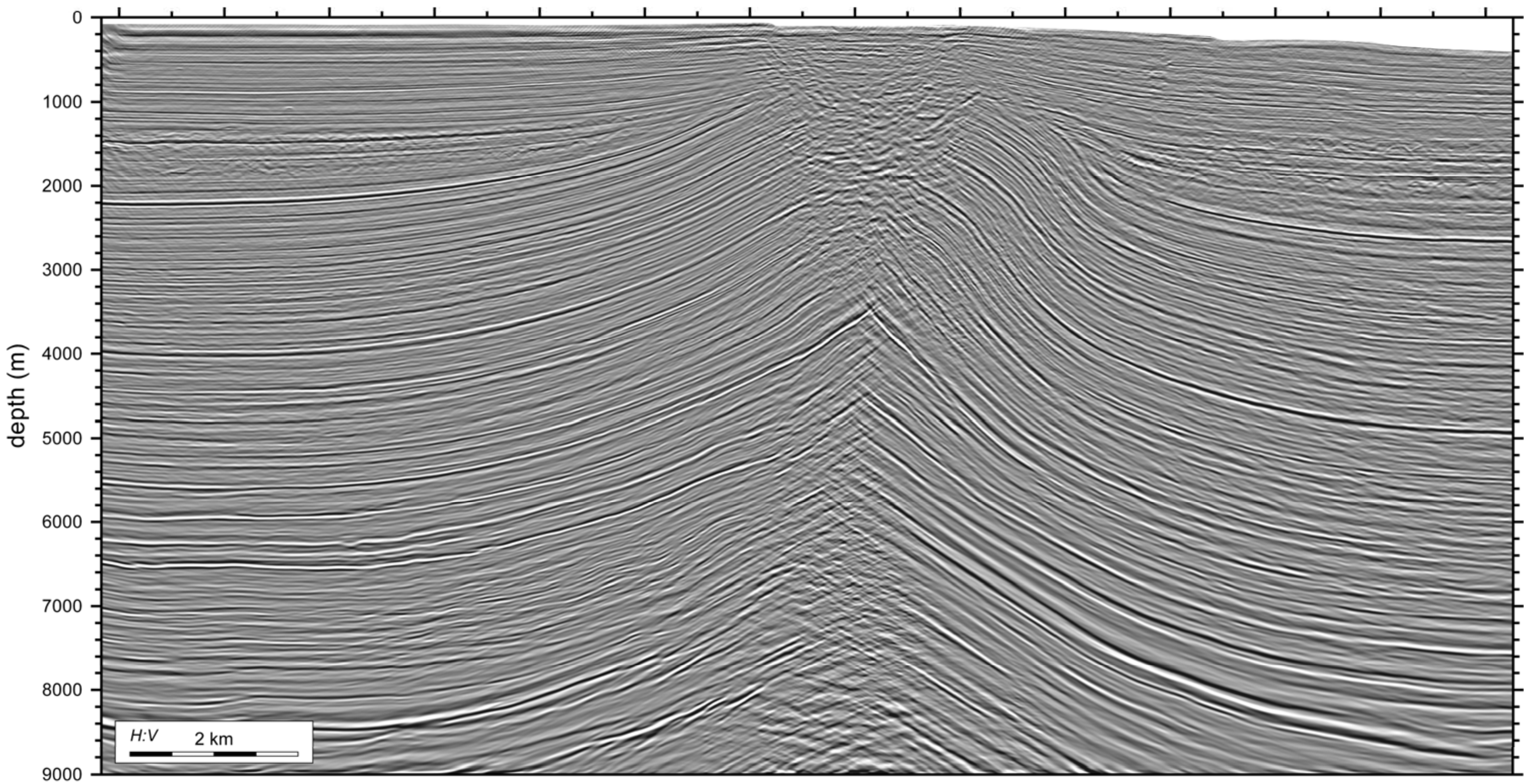



AAPG 2011
Annual Convention
& Exhibition
10-13 April 2011 • Houston

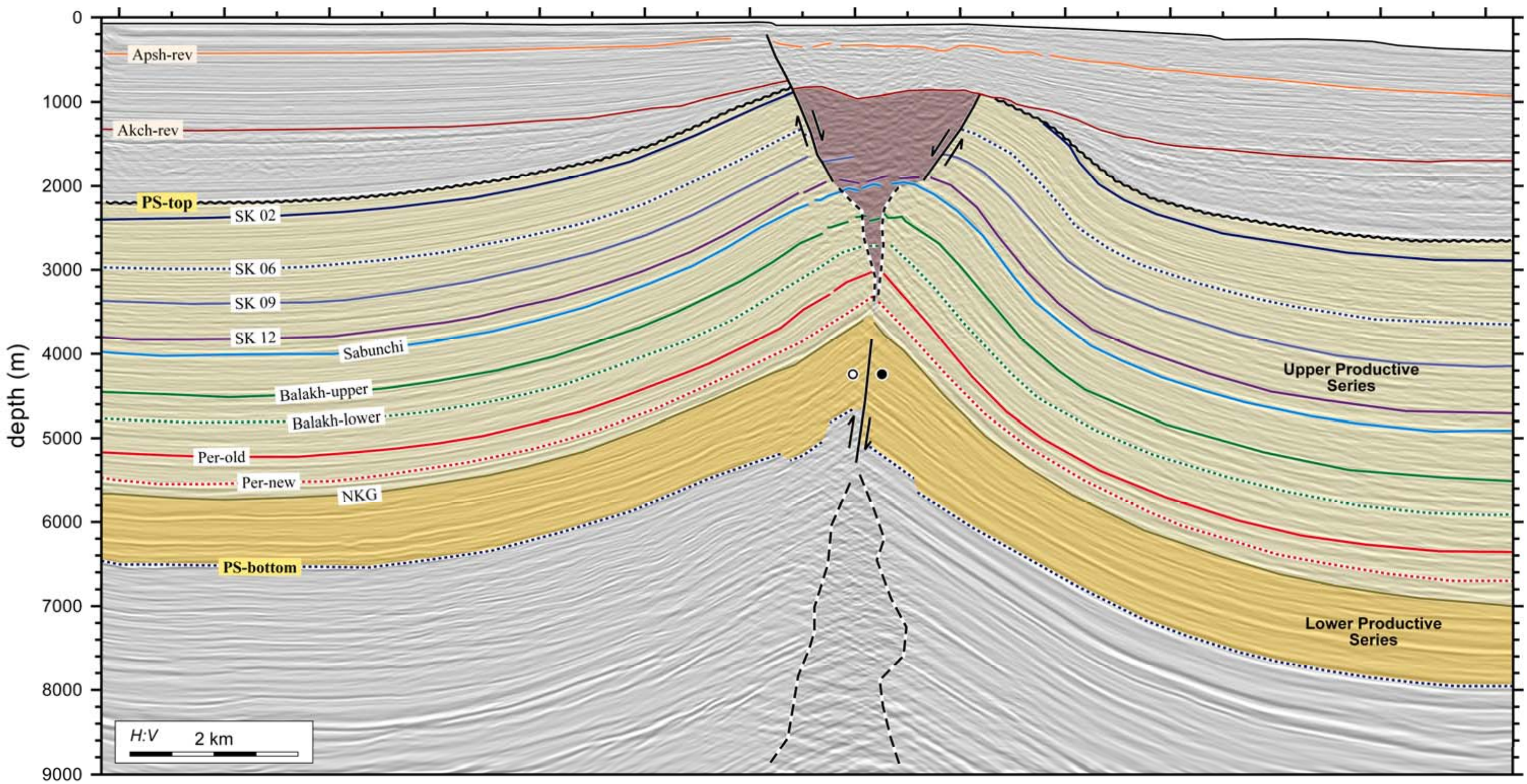
2. Structure


0
1000
2000
3000
4000
5000
6000
7000
8000
9000
depth (m)
Apsh-rev
Akch-rev
PS-top
SK 02
SK 06
SK 09
SK 12
Sabunchi
Balakh-upper
Balakh-lower
Per-old
Per-new
NKG
PS-bottom
Upper Productive Series
Lower Productive Series
H:V
2 km

2. Structure



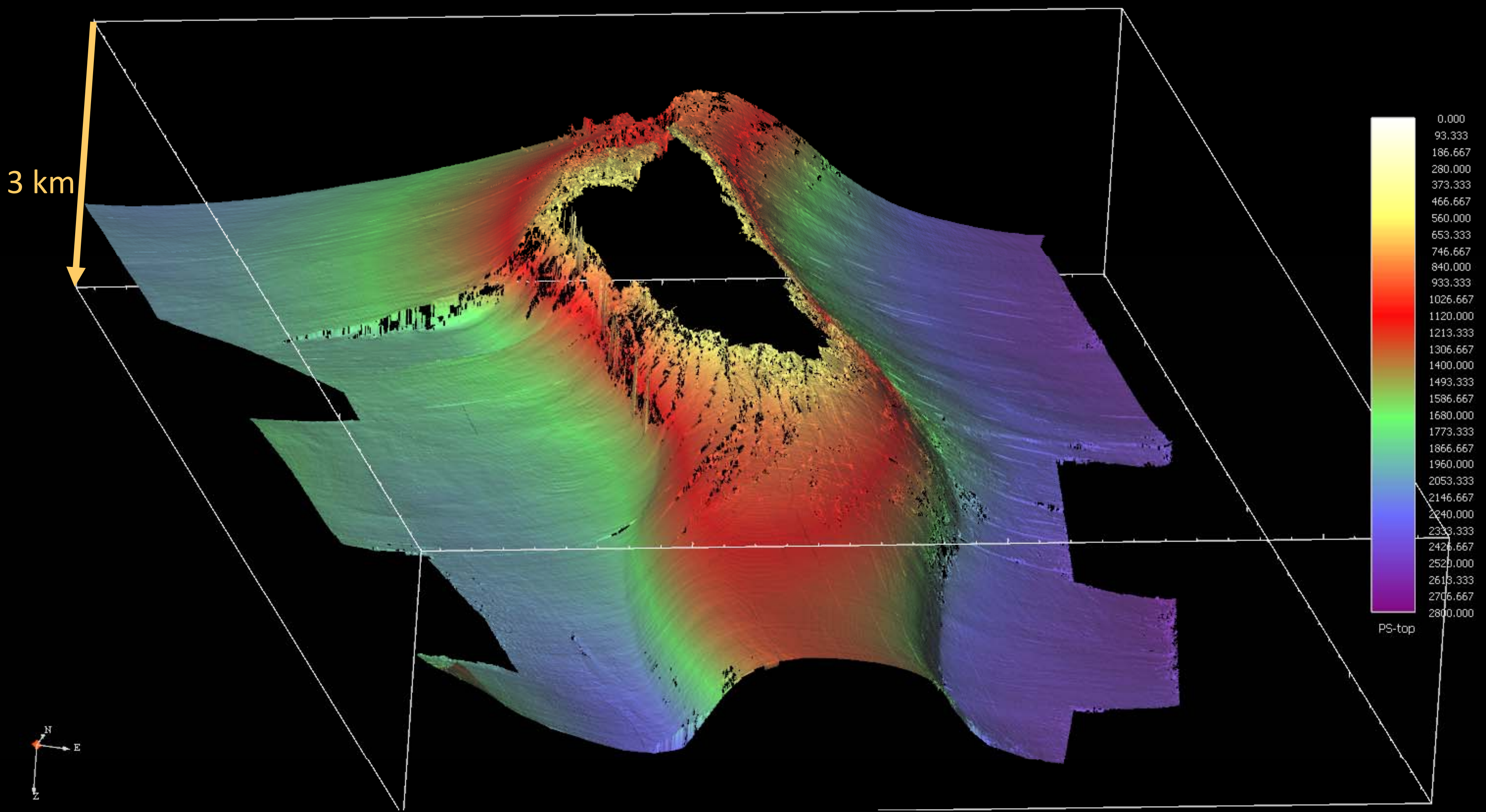
2. Structure



0
1000
2000
3000
4000
5000
6000
7000
8000
9000
depth (m)
Apsh-rev
Akch-rev
PS-top
SK 02
SK 06
SK 09
SK 12
Sabunchi
Balakh-upper
Balakh-lower
Per-old
Per-new
NKG
PS-bottom
Upper Productive Series
Lower Productive Series
H:V
2 km

2. Structure

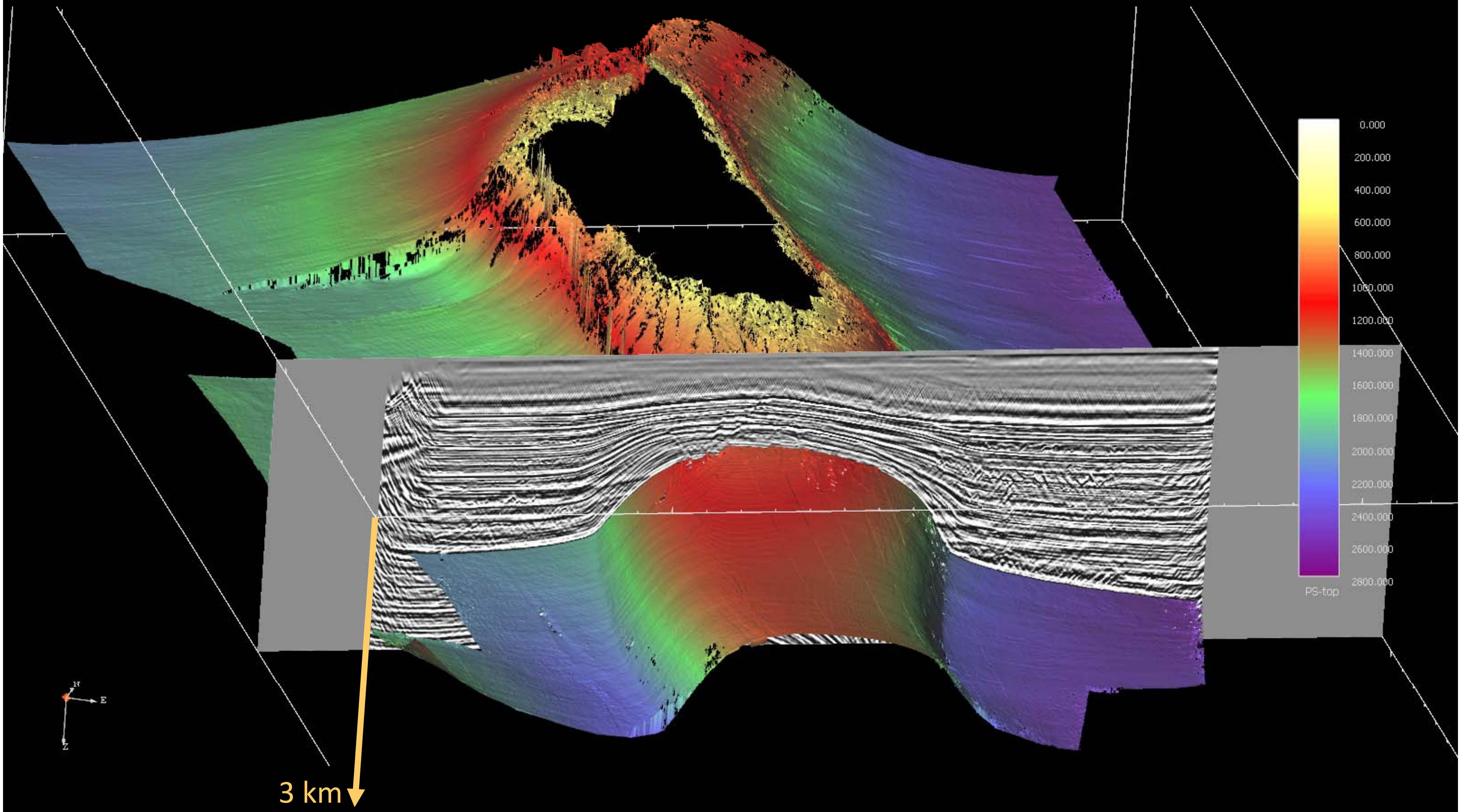
PS-top (3.1 Ma)



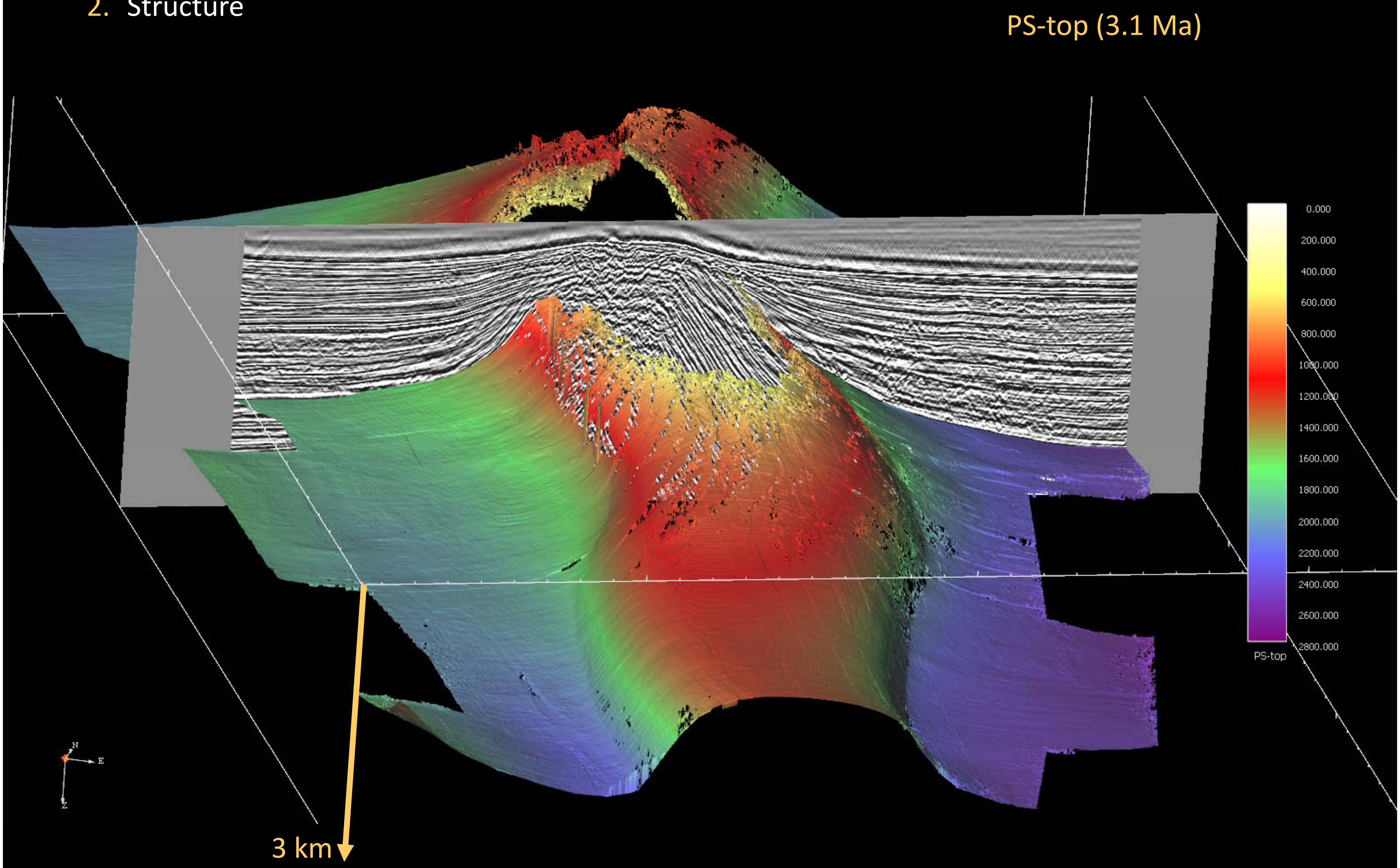
AAPG 2011 Annual Convention & Exhibition 10-13 April 2011 • Houston

2. Structure

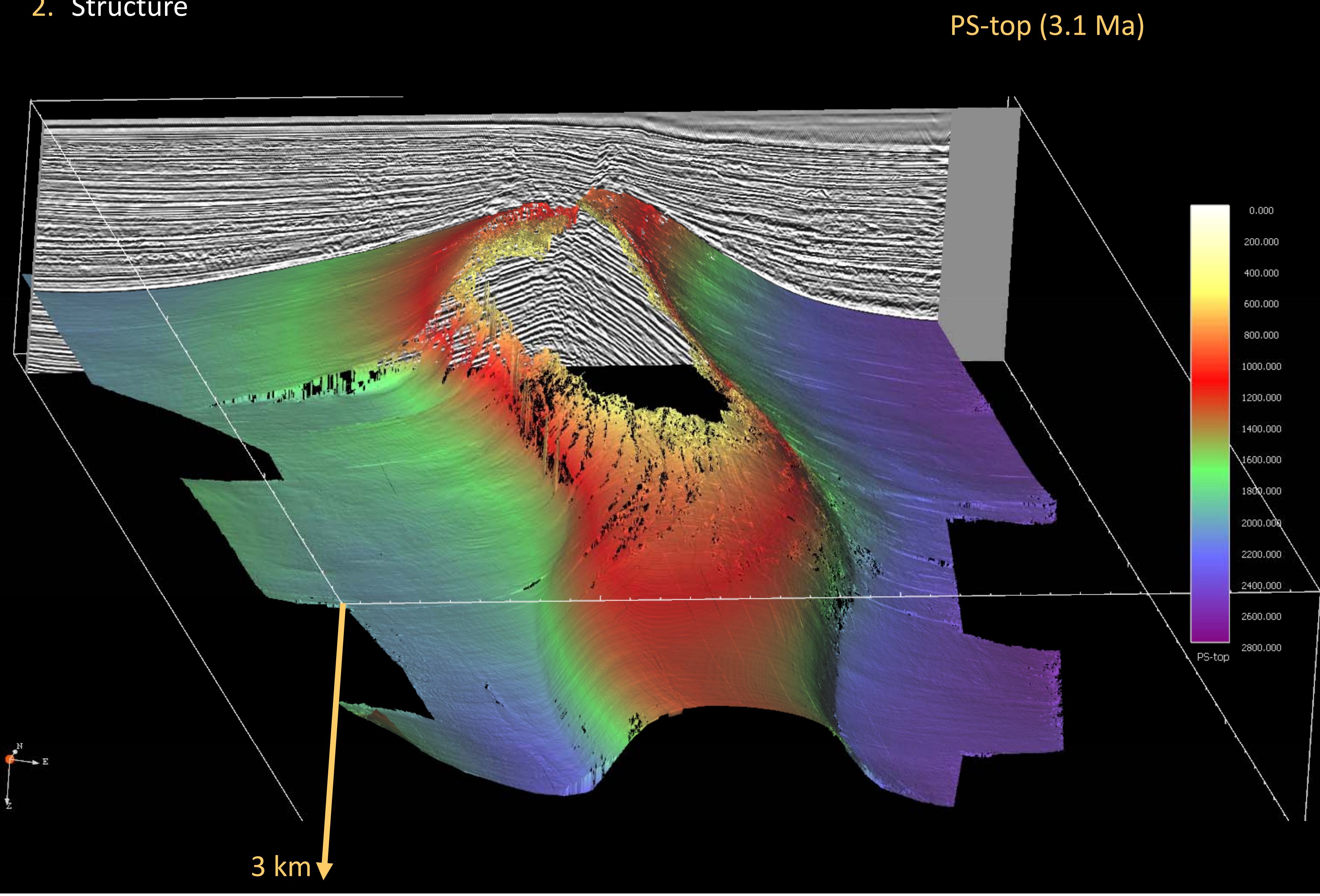
PS-top (3.1 Ma)



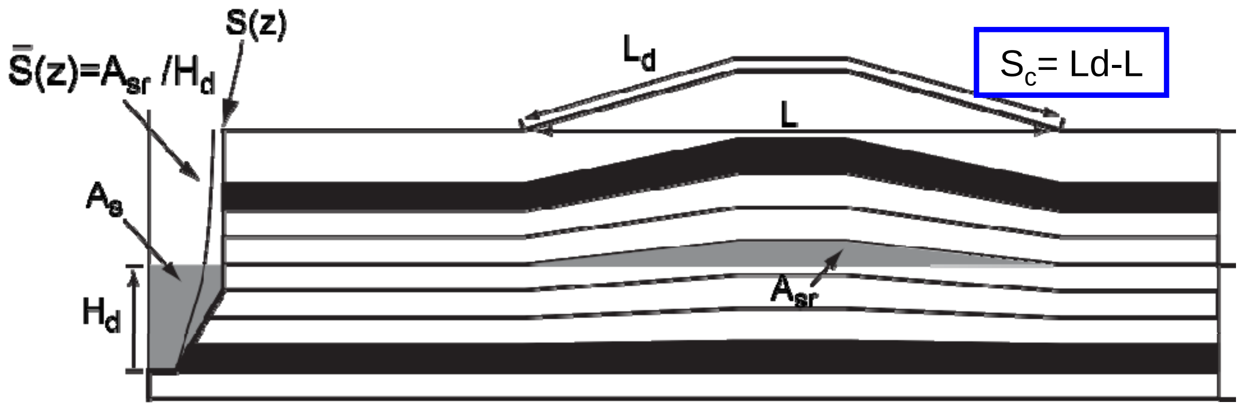
2. Structure

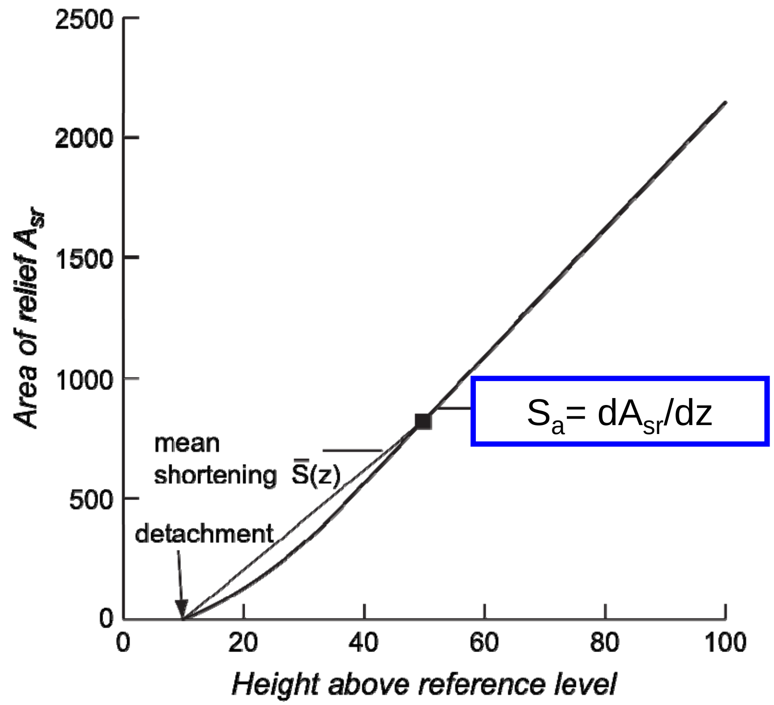

PS-top (3.1 Ma)
0.000
200.000
400.000
600.000
800.000
1000.000
1200.000
1400.000
1600.000
1800.000
2000.000
2200.000
2400.000
2600.000
2800.000
PS-top
N
E
Z
3 km

2. Structure


PS-top (3.1 Ma)
0.000
200.000
400.000
600.000
800.000
1000.000
1200.000
1400.000
1600.000
1800.000
2000.000
2200.000
2400.000
2600.000
2800.000
PS-top
N
E
Z
3 km

3. Shortening magnitude and history



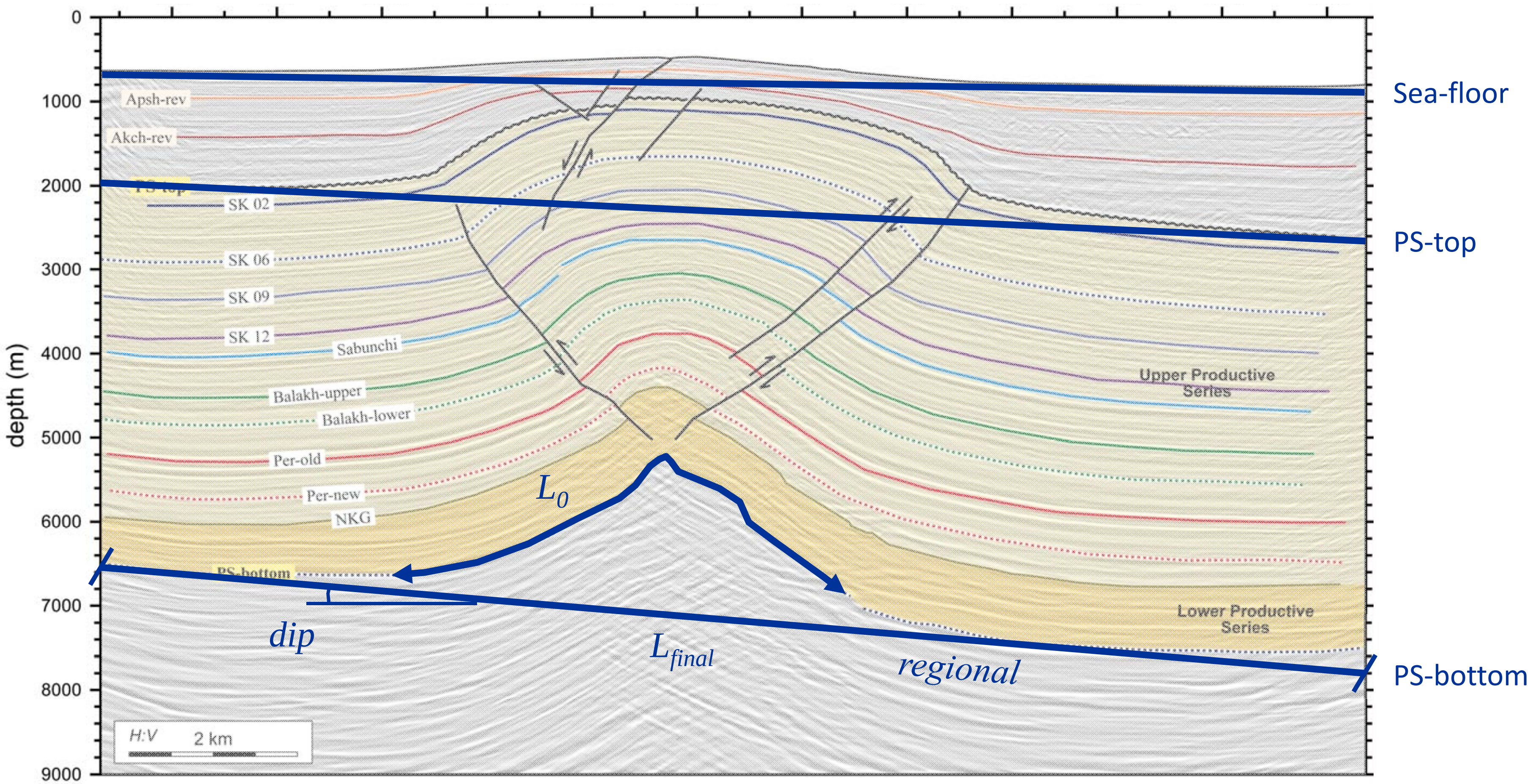


Shortening:

- curvimetric (S_c)
- S_a, based A_{sr}/z

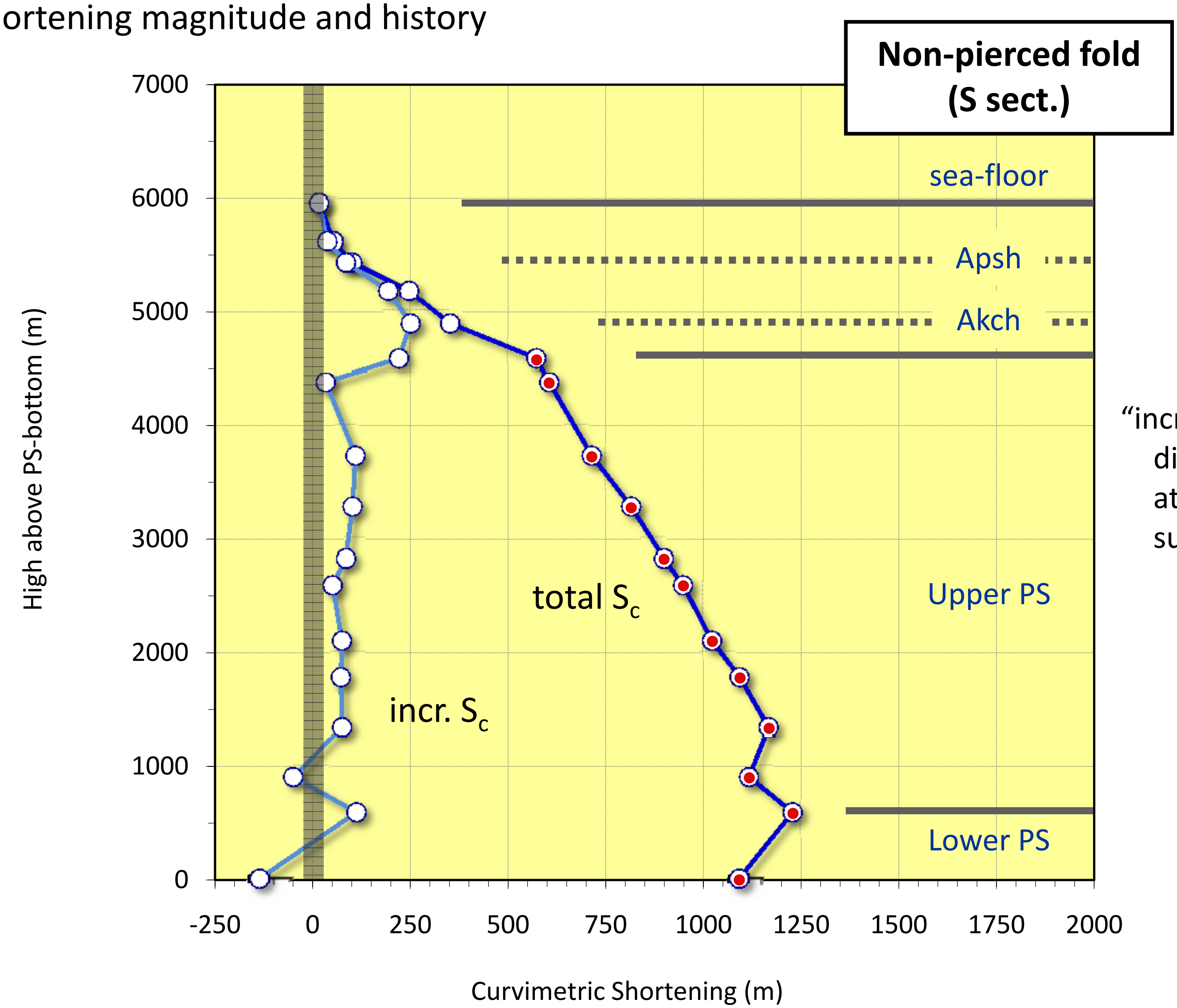
González-Mieres and Suppe (2006)
Epard and Groshong (1993)
Poblet et al. (2004)

3. Shortening magnitude and history



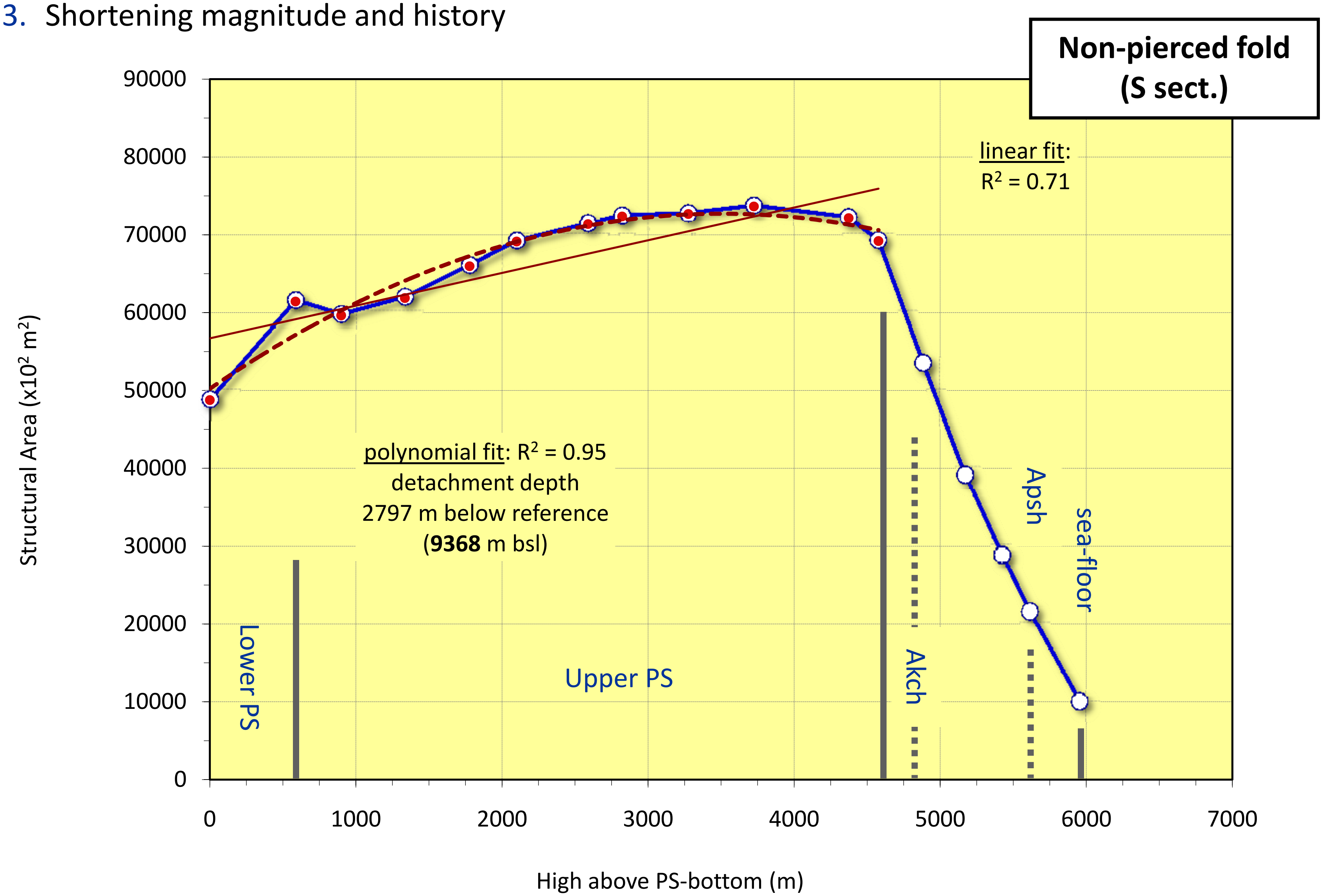
Non-parametric Statistics is used to fit the complete fold shape

3. Shortening magnitude and history

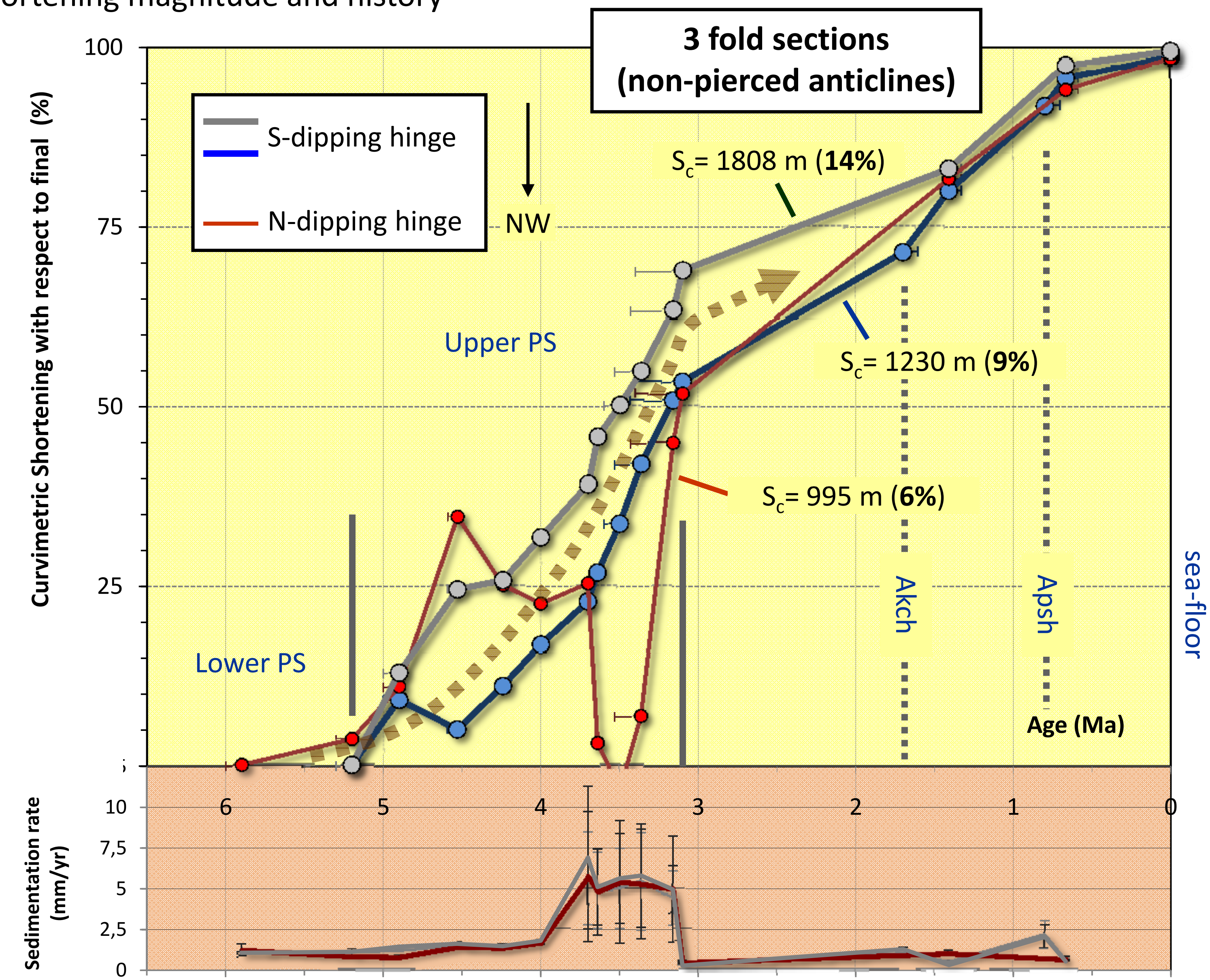


"incremental" S_c= difference between S_c at bottom and upper surfaces per layer

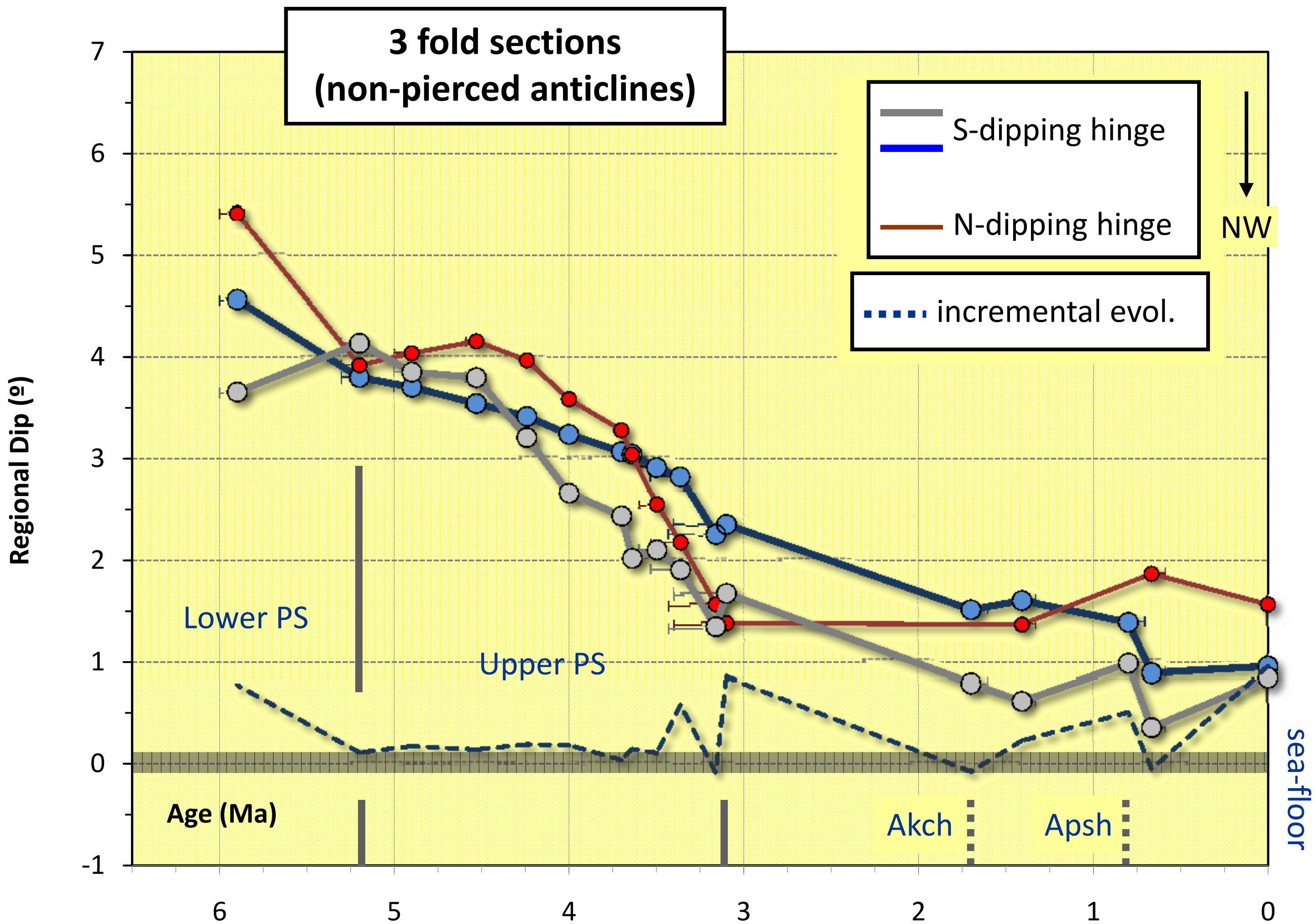
3. Shortening magnitude and history



3. Shortening magnitude and history



3. Shortening magnitude and history



Conclusions

- Anticline culmination shows a sigmoidal axial trace with curved and nearly-radial, crestal faults
- The apparent pre-growth sequence represented by the PS series (> 3.1 Ma) register ~55-70% of the total shortening
- An early folding event is identified at the end of the PS series, during Surakhani deposition (~3.2-3.6 Ma), which coincides with a pulse in basin tilt and high sedimentation rates (5-6 mm/y)
- The syn-growth (<3.1 Ma) fold evolution had a maximum shortening event at ~1.7 Ma (Akchl·Ǝȅſ), decreasing monotonically up to Present

Conclusions

- Overpressured-mud crosscuts the anticline structure in those sections with shortening >15%
- This detachment anticline has a decoupling layer/surface placed at 9.5-10 km depth.
- The studied fold has a rounded geometry that departs from the standard detachment-fold model shaped by parallel layers