The NW Black Sea Region in the Dawn of the Phanerozoic*

Bogdan M. Popescu[1], Mihai Micu[1], and Emilia Ranete[1]

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[1]Zeta Petroleum Romania Srl, Bucharest, Romania (bpopescu@zetaromania.com)

Abstract

The area under discussion is located east of the onshore Prut-Danube Fault running N-S close to the 28° E meridian and extending offshore Black Sea roughly to the 31°E Meridian. It includes, from North to South, the present-day Baltica or East Europe Craton (EEC), Moldova Basin (MB), North Dobrogea Domain (NDD), and Moesia (Mo). These elements are roofed by rather flat Jurassic to Neogene sequences.

At the end of the Precambrian, there were two main terrane opposing each other: Baltica and Gondwana and, in-between, peri-Gondwanan terranes that included Scythia. The interaction between these terranes at the time of our reconstruction is obscured essentially by the Jurassic-Neogene sequences of the Moldova and Euxinian basins. They cover the continent-to-continent suture between EEC and Scythia, represented by the Murgoci-Golitsyn Fault Zone (Starostenko et al., 2013, Popescu et al., 2016) or, in a different interpretation, by the Variscan Thrust front (e.g., Yudin, 2012). Results of refraction seismic (Starostenko et al., 2013, 2015, 2017) show, in our interpretation, Scythia crust slightly overriding the buckling Baltican mantle. Moreover, there is a contrasted behavior of the Scythia crust west and east of the Nistru (Dniester) Fault; this, in particular, remains to be clarified. West of the Nistru Fault, the Moldova Basin lies over a westward-tilting Scythian upper crust compared to the almost flat Baltican one. Refraction seismic shows a spectacular, 15-18-km amplitude buckling of Baltica's Moho. We propose it was initiated by the almost continuous collision push of Scythia during the Cadomian and Caledonian contractions, continued, at varying intensities, by the long-term compression that had been persistent in the Variscan and Cimmerian orogenies, followed by the Early Cretaceous rifting, Late Cretaceous closing of the Tethys oceans and the Eocene-Miocene inversions. They all contributed to the present map-view mosaic of blocks in the Moldova Basin, i.e., the sedimentary cover of Scythian basement.

Whereas Moho is clearly defined on the refraction seismic, there is no clear upper crust velocity field variation when moving laterally from the Baltica to younger, e.g., Scythia, tectonic units (Starostenko et al., 2013), perhaps for similar densities although different-age crusts. West of the Nistru Fault the Scythia is supposed having WEP affinities (Starostenko et al.,2015). Yet, we can recognize on the DOBRE sections the crustal continuation of the Murgoci-Golytsin Lineament (a segment of the 2000-km-long Scytho–Turan Suture), where Moho appears to be some 5km higher below Scythia. Similar offset, based on reflection seismic, was noticed in the onshore western basement compartment of the the Nistru Fault, which is 4km down compared with the eastern one (Samsonov et al., 2002).

In summary, we consider that the initiation in the Late Precambrian and Early Paleozoic movement of Scythia over/or against the Baltica followed by long-term compressional regime explains better the distinction we made between the roughly E-W *Scytho-Turan* compressional suture and the roughly NNW-SSE *Teisseyre-Tornquist* transtensive suture. In our view they cut at an angle the Baltica's, present-day southwestern corner located in Romania, with the former suture being younger than the latter.

Selected references

Bush, V.A., 2014, The deep structure of the Scythian plate basement: Geotectonics, v. 48/6, p. 413-426.

Kheraskova, T.N., V.A. Bush, A.N. Didenko, and S.G. Samygin, 2010, Breakup of Rodinia and early stages of evolution of the Paleoasian Ocean: Geotectonics, v. 44/1, p. 3-24.

Kheraskova, T.N., Yu.A. Volozh, M.P. Antipov, V.A. Bykadorov, and R.B. Sapozhnikov, 2015, Correlation of Late Precambrian and Paleozoic events in the East European platform and the adjacent paleooceanic domains: Geotectonics, v.49/1, p. 27-52.

Linnemann, U., R.S. D'Lemos, K. Drost, T.E. Jeffries, R.L. Romer, S.D. Samson, and R.A. Strachan, 2008, Cadomian tectonics, *in* T.McCann, editor, The Geology of Central Europe, v. 1 – Precambrian and Paleozoic: Geological Society, London, p. 103-154.

Matenco, L., G. Bertotti, K. Leever, S. Cloeting, S.M. Schmid, M. Tărăpoancă, and C. Dinu, 2007, Large scale deformation in a locked collisional boundary: Interplay between subsidence and uplift, intraplate stress and inherited lithospheric structure in the late stage of SE Carpathians evolution. Tectonics, 26, p. 1-29.

Popescu, B.M., M. Micu, and G. Tari, 2016, The Moldova slope and basin development in the Ediacaran-Early Paleozoic: A collage with multiple structural overprints: Search and Discovery Article #10887 (2016). Website accessed March 1, 2018, http://www.searchanddiscovery.com/documents/2016/10887popescu/ndx_popescu.pdf.

Popovici, S.V., 1989, Structural peculiarities of the Mezo-Cainozoic formations on the northwestern shelf of the Black Sea: Geotectonika, v. 6, p. 81-89.

Seghedi, A. 2009, Paleozoic terrane accretion and Mesozoic evolution of the NW margin of the Black Sea: 2nd International Symposium on the Geology of the Black Sea Region, Abstract Book, Ankara, Turkey, 5-9 October, 2009, p. 178-180.

Seghedi, A., G. Tari, and M. Ducea, 2016, Deep marine Paleozoic deposits of the Tulcea Zone, North Dobrogea – fragment of a Variscan back-arc basin? (Abstract): AAPG European regional Conference & Exhibition 19-20 May, Bucharest.

Sliusar, R.B., 1984, The structures of the horizontal compression in the northern Predobrogean region: Academy of USSR, Geotektonica, (in Russian).

Starostenko, V., T. Janik, T. Yegorova, L. Farfuliak, W. Czuba, P. Środa, H. Thybo, I. Artemieva, M. Sosson, Y. Volfman, K. Kolomiyets, D. Lysynchuk, V. Omelchenko,D. Gryn, A. Guterch, K. Komminaho, O. Legostaeva, T. Tiira, and A. Tolkunov, 2015, Seismic model of the crust and upper mantle in the Scythian Platform: the DOBRE-5 profile across the north western Black Sea and the Crimea Peninsula. Geophysical Journal International, .v. 201, p. 406-428.

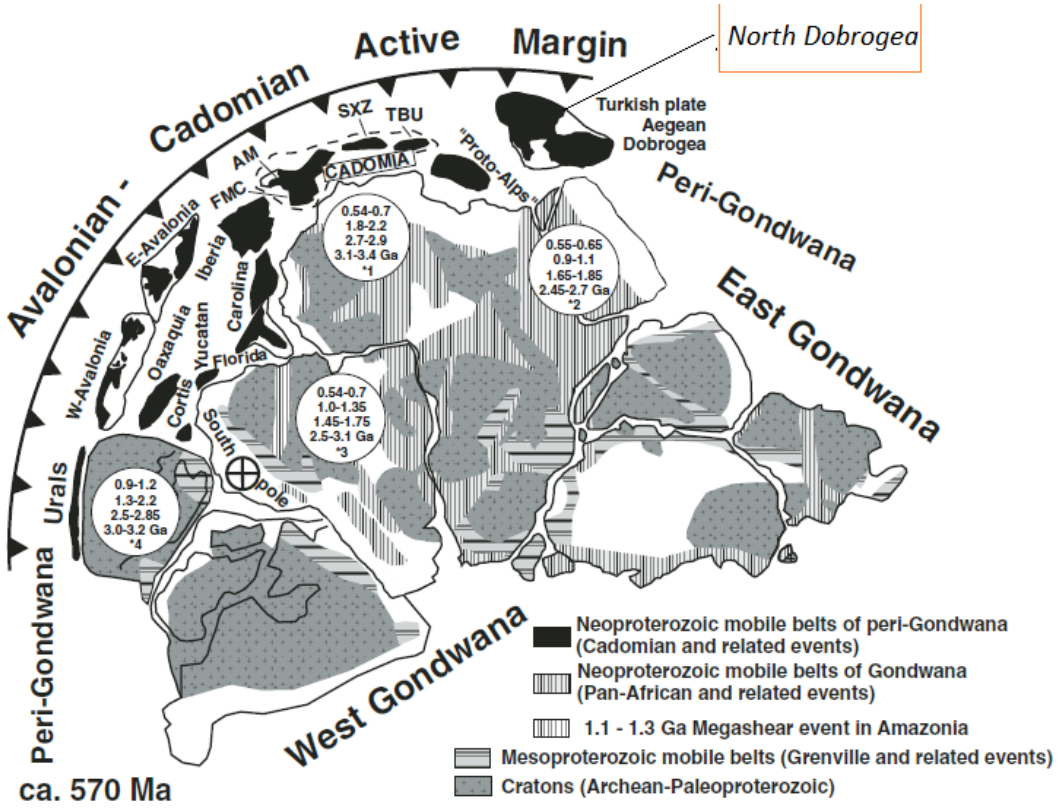
Tari, G., M. Fallah, W. Kosi, Z. Schleder, V. Turi, and C. Krezsek, 2015, Regional rift structure of the western Black Sea Basin: Map-view kinematics, in Petroleum Systems in “Rift” Basins: SEPM Society for Sedimentary Geology, v. 34, p. 372-395.

Yudin, V.V., 2012, Geodynamic Complexes of Crimea (in Russian): LAP LAMBERT Academic Publishing, Germany, 61p.

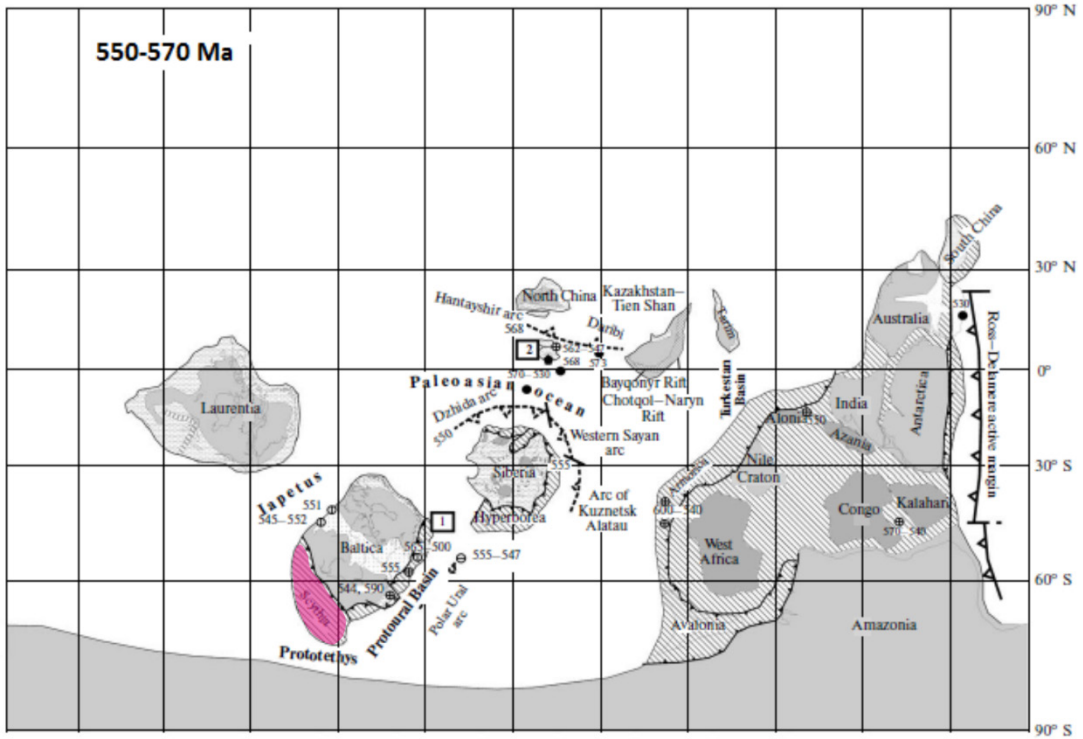
THE NW BLACK SEA REGION IN THE DAWN OF THE PHANEROZOIC

POPESCU, B., MICU, M., RANETE, E.
(Zeta Petroleum Romania Srl)

Position of North Dobrogea (Scythia) in the Late Ediacaran



From Linnemann et al 2007



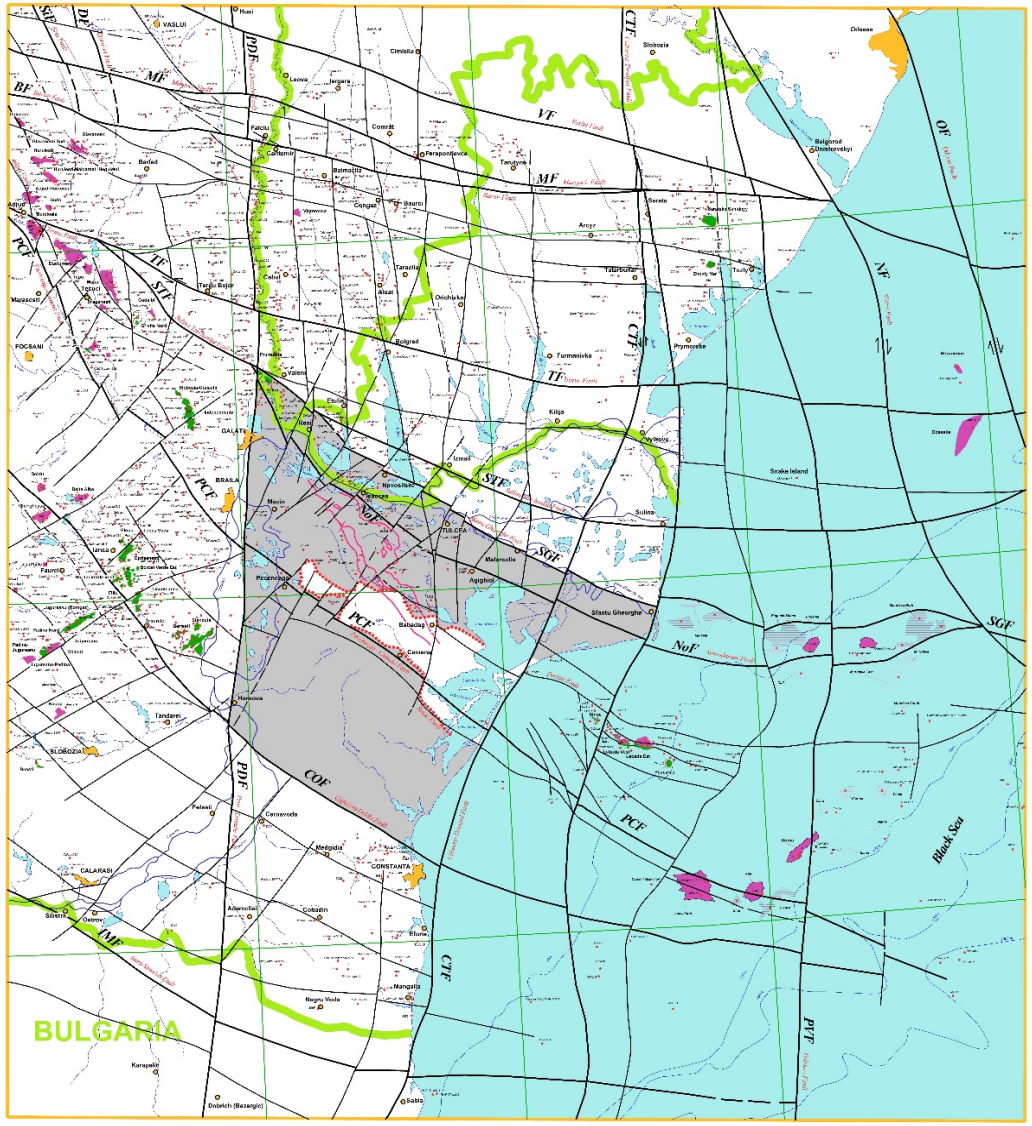
From Kheraskova et al 2010

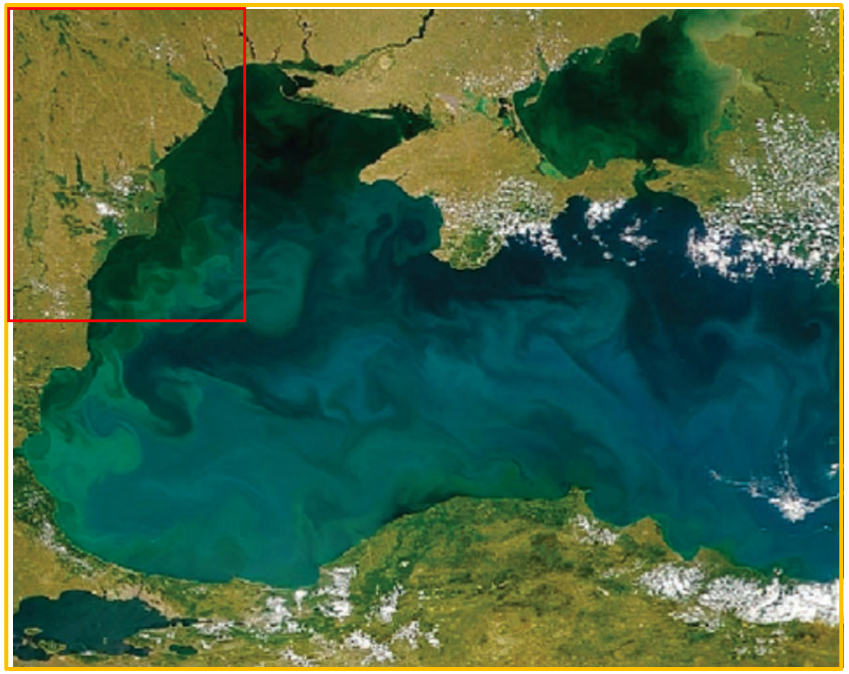
Presenter's notes: Before final collision of Scythia (Nord Dobrogea and Pre-Dobrogea = Moldova Basin) to southern Baltica 30-50Ma later..

Introduction

- In the late Ediacaran/Early Palaeozoic this region was the place where the impact of two terranes is identified as the overriding Scythia and the passive margin Baltica (e.g., Popovici, 1989; Yudin, 2012; Bush, 2014;, Kheraskova, 2015; Popescu et al., 2016).
- Scythia's demarcation has been poorly defined in the study area. There are two dominant opinions regarding the suture between the Scythia and Baltica: i) a majority of researchers (e.g., Starostenko et al., 2013-2017 and references therein) preferring the Golitsyn-Azov Fault continued westward by the Murgoci Fault Zone (Popescu et al., 2016) and eastwards into Scytho-Turan Fault (Bush, 2014; Kheraskova, 2015); ii) a smaller group tracing it along the North Crimea suture (e.g., Yudin 2012) that seems to continue westwards of the Odessa-Nistru Fault Zone, with the Trotus Fault.
- The Scythia terrane extended north to the oblique Peceneaga-Camena Transform Fault and accreted older peri-Gondwanan micro- terrane splinters named Macin and Niculitel, while the Tulcea Unit is represented in the southern retroforeland basin.
- It was thus proposed that Scythia – the informal *Scythian Platform*, a Hercynian – Cimmerian showcase - is a much older setting that bears records of older orogenies: Cadomian and Caledonian both reckoned in the N. Dobrogea Highland (Popescu et al., 2016) on scarce outcrop evidences.

Pre-Neogene Tectonic Map of the NW Black Sea Area



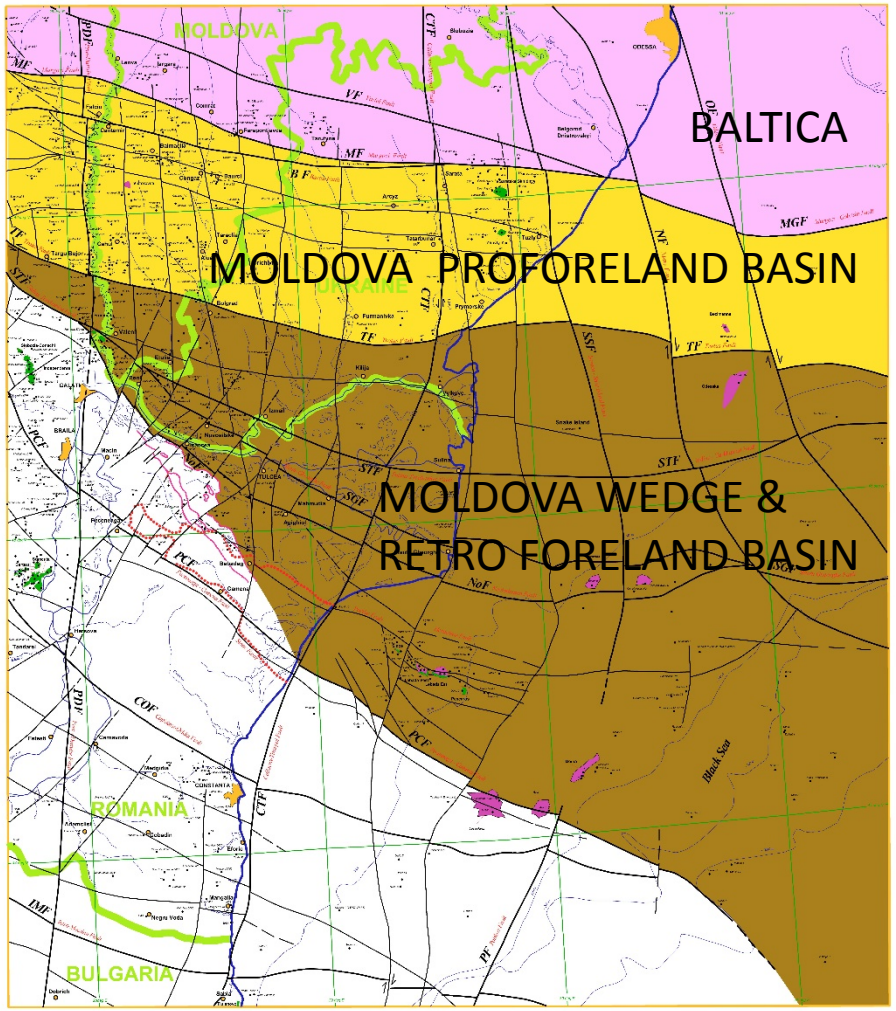


Presenter's notes: The focus area lies between the N-S Prut-Danube (Danube) Crustal Fault (PDF) and Odessa (OF)— Nistru (NF) transform faults and is bounded to the north by the Murgoci Fault Zone (BF, MF, VF) and to the south, by the Peceneaga Camena Transform Fault (PCF) .

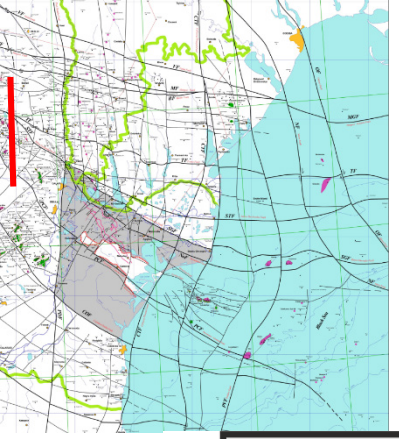
This map shows the SW Baltica corner and the westernmost development of Scythia. The main discussion has been related to the position of the suture between these two terranes. Some authors (e.g., Starostenko et al., 2013-17; Kozlenko & Kozlenko, 2014) prefer the pre-Variscan Murgoci Fault Zone - Golitsyn Fault suture, others, east of Nistru (Dniester) – Odesa faults (e.g., Yudin, 2012) prefer the Variscan North Crimea suture.

Depending on these interpretations the (Post -Cadomian) Moldova Basin would be placed on the southern passive margin of the Baltica or over the Scythia micro-plate basement.

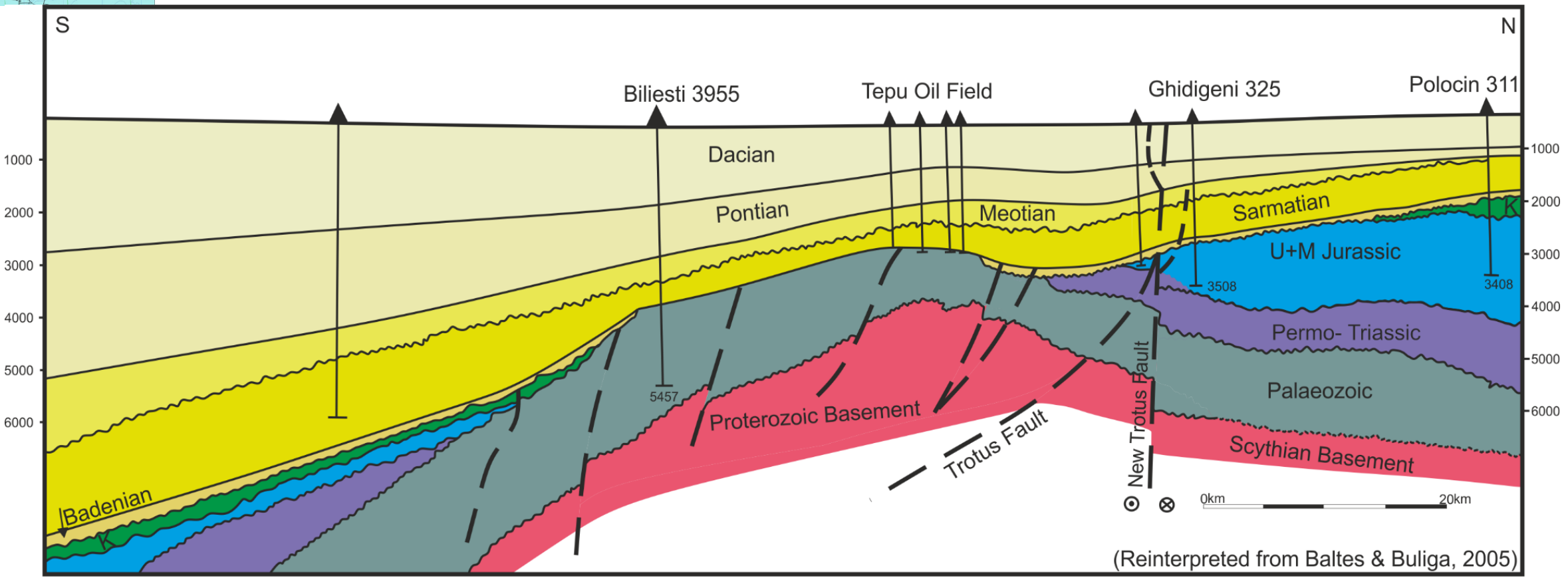
Main Tectonic Units of the NW Black Sea in Late Paleozoic



Presenter's notes: Scythia is a peri-Gondwanan terrane that accreted to Baltica during the Cadomian contraction period (Kheraskova, 2015 ; Popescu et al., 2016) or much later, during the Variscan period (e.g., Yudin, 2012). Kheraskova et al. (2010) favour a Rodinian origin of the Scythia micro-Plate.
The pre-Jurassic map-view shows the northern Baltica with a thin cover of Ediacaran-Devonian sediments.

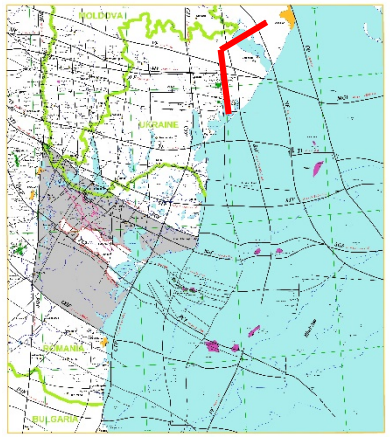


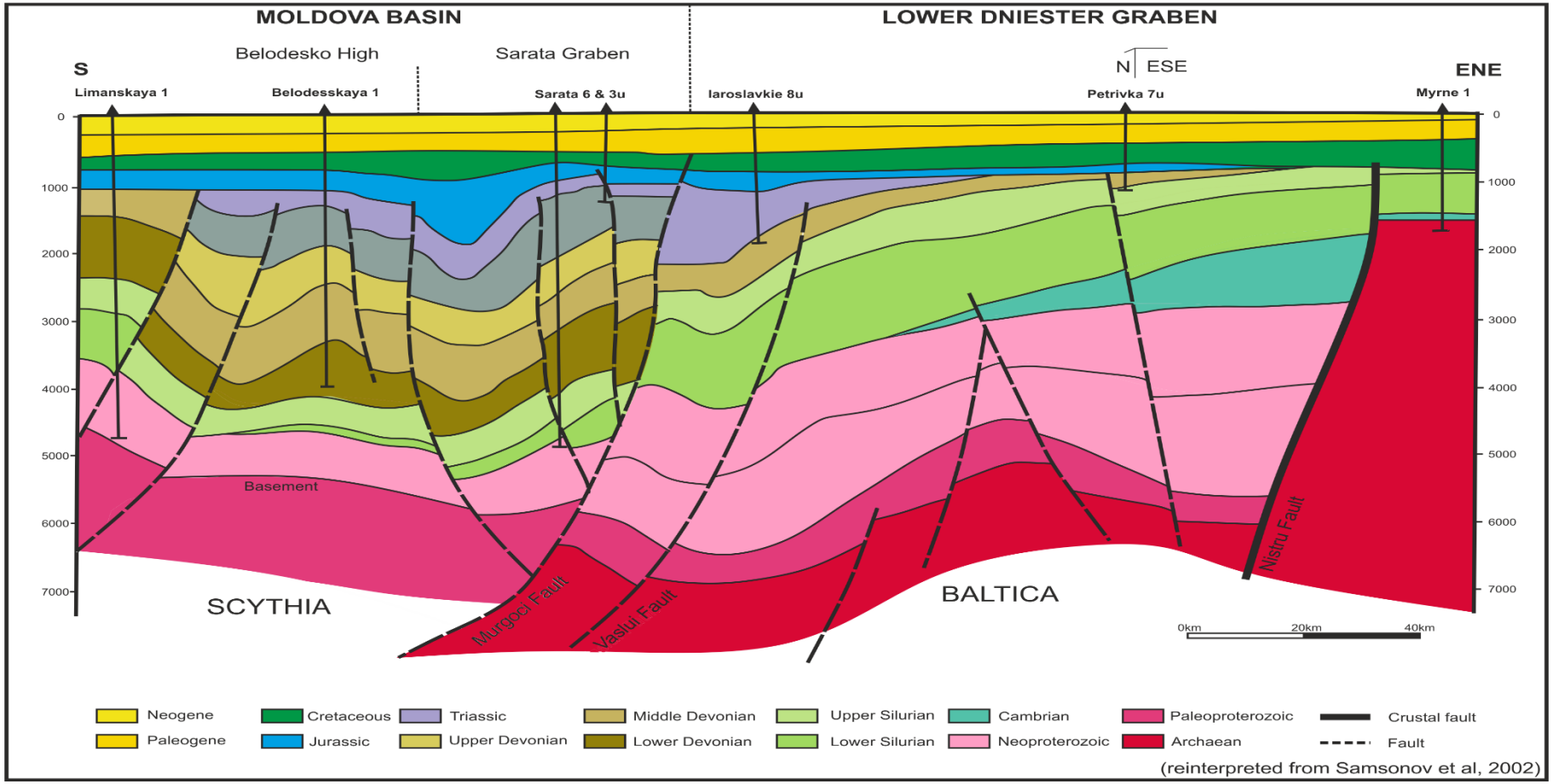
Cross-section in the central Bârlad Subbasin



Presenter's notes: A westernmost Scythia's transversal cross section shows the Variscan-Cimmerian Trotus Thrust Fault and its Neogene reactivation, through the sinistral strike-slip, New Trotus Fault. The latter disappears in a splay of satelite faults west of the sub-meridian Prut-Dunare (Danube) Fault.

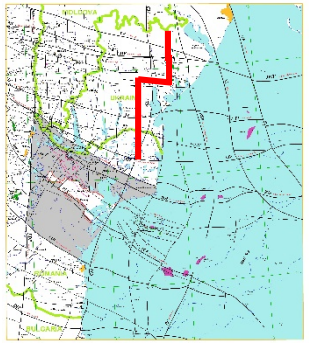
Cross-section from Baltica to Moldova Basin in eastern onshore Ukraine (I)

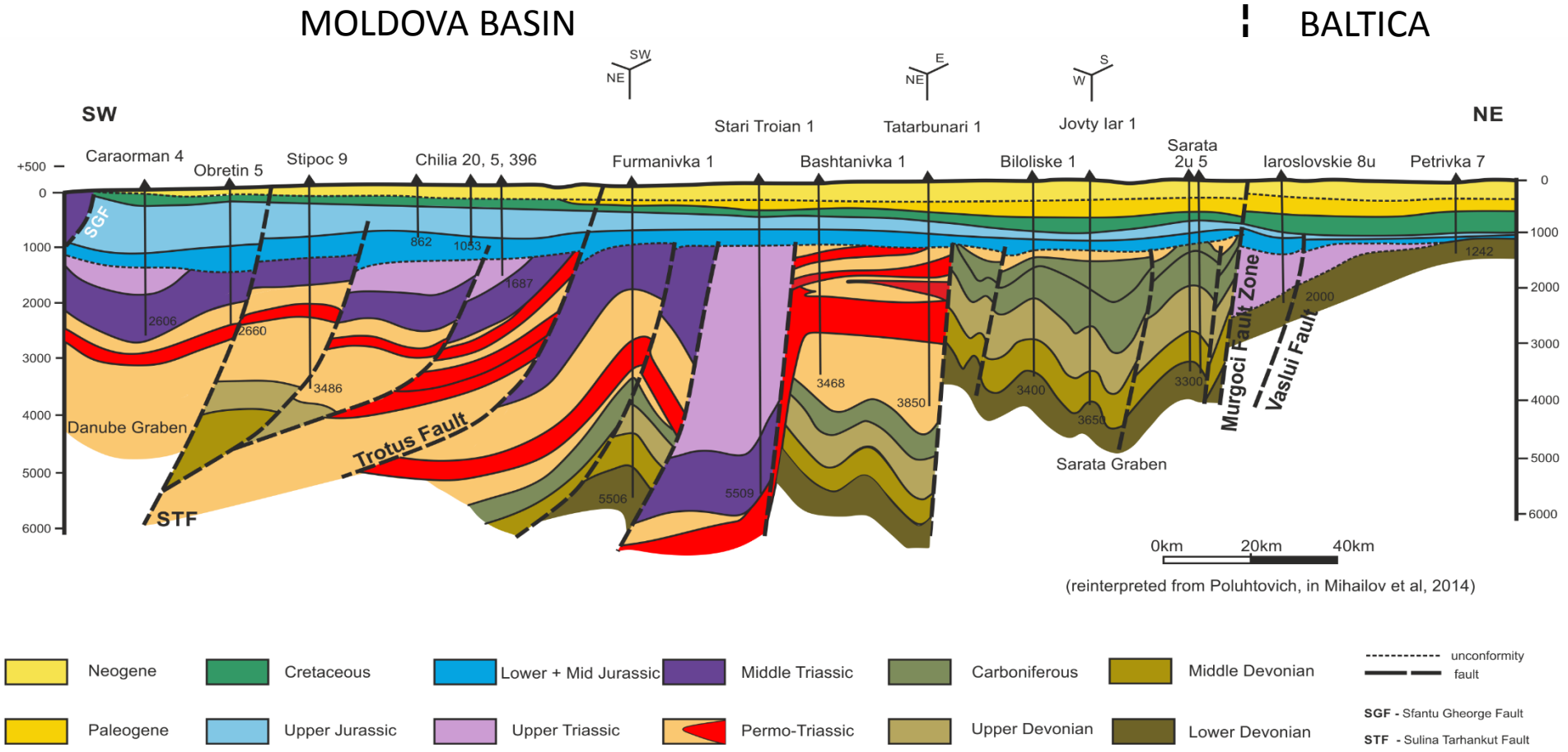




Presenter's notes: Samsonov et al. (2002) depict the dramatic (?pre-Cadomian) downthrown hangingwall of Baltica along the Nistru Fault. Note our interpretation of the slightly obducted Scythia over Baltica.

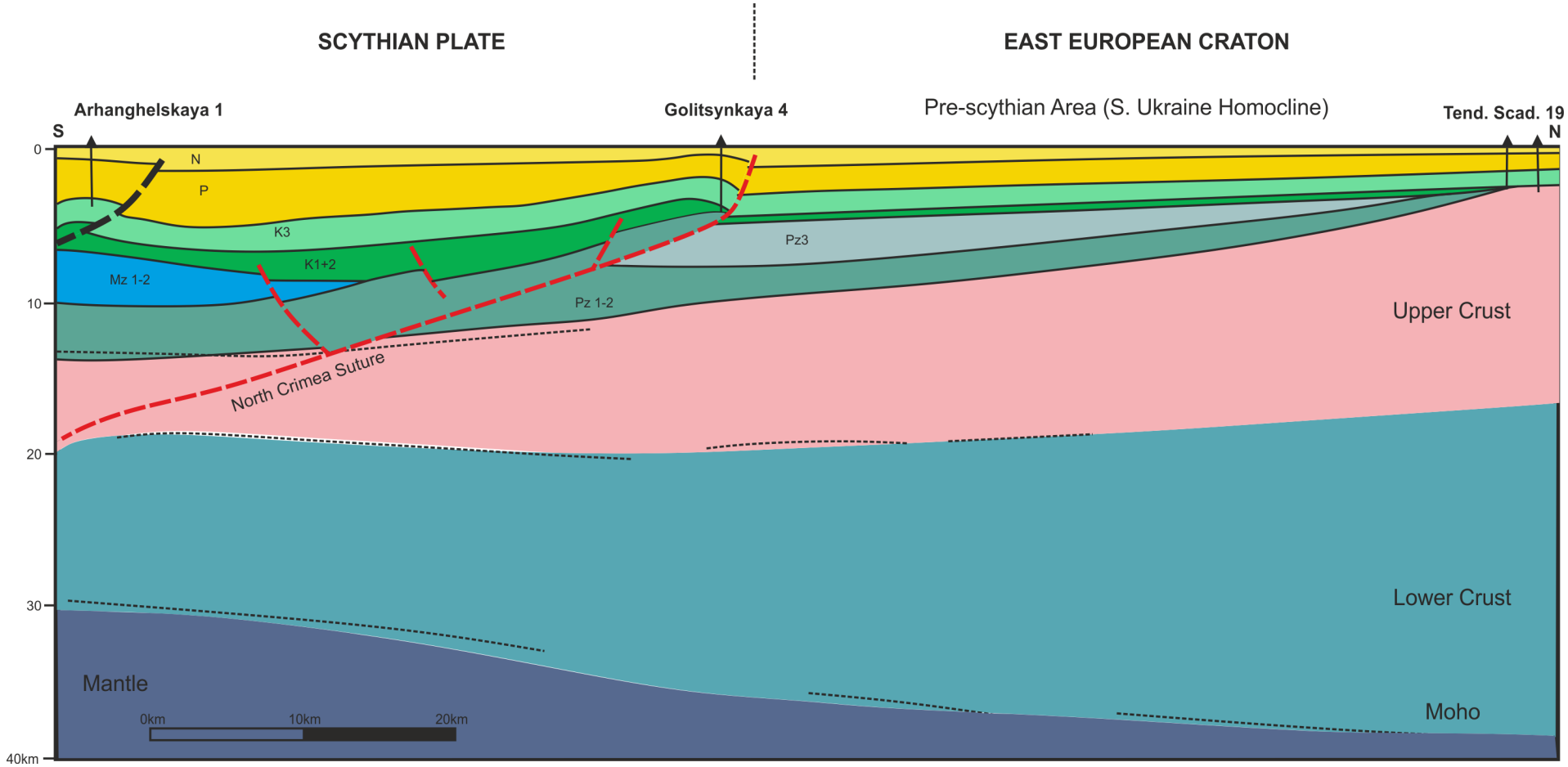
Cross-section from Baltica to Moldova Basin in eastern onshore Ukraine (II)





Presenter's notes: The Trotus Fault is Variscan-Cimmerian sealed by the Upper Jurassic deposits. Note the strong Permo-Triassic rifting south of the Sarata Graben. SGF= Sfântu Gheorghe Fault; STF= Sulina Tarkhankut Fault.

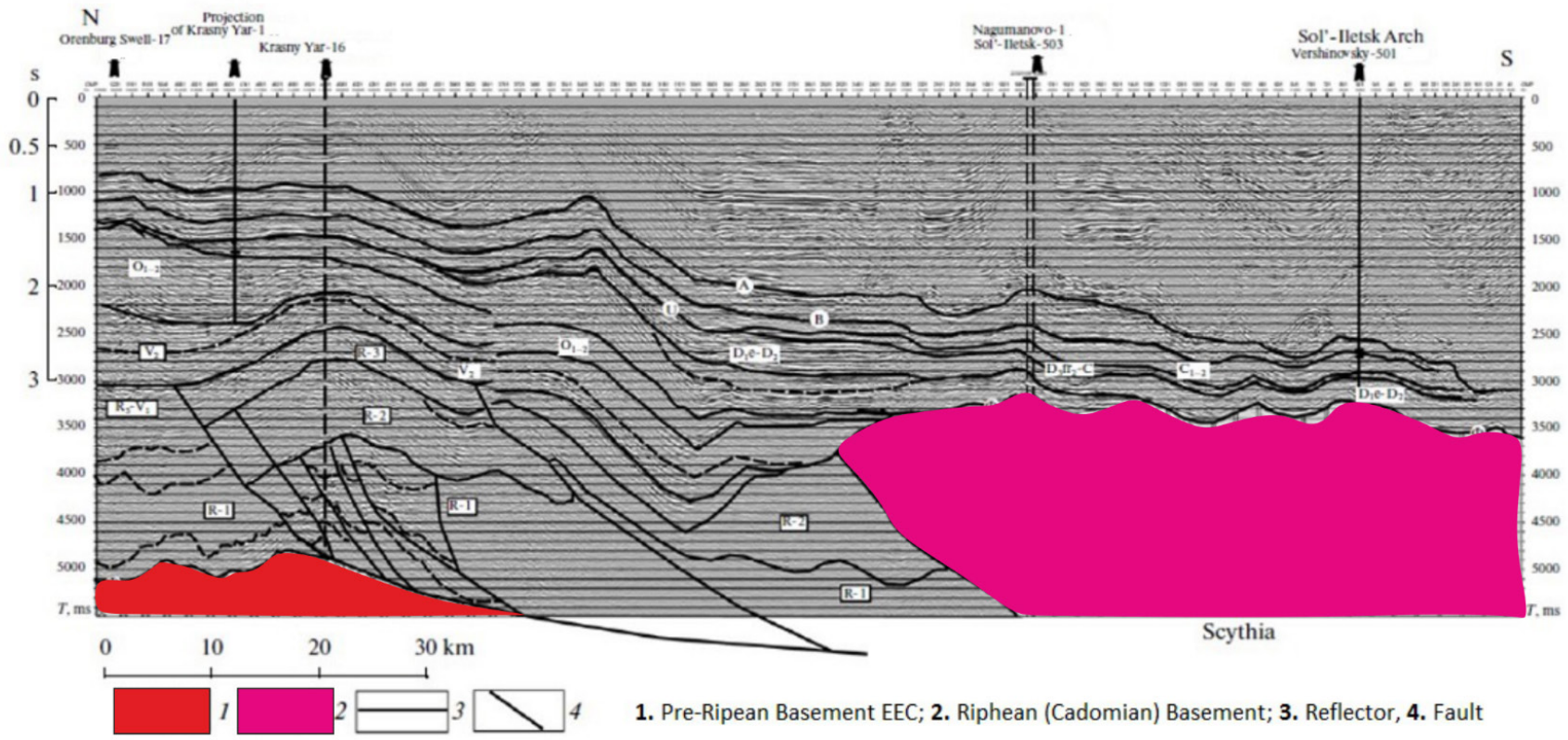
North-South Cross-section East of Odessa Fault



Redrafted from Yudin 2012

Presenter's notes: The North Crimea Suture could be the correspondent of the Trotus Fault east of the Nistru-Odesa Transform Fault.

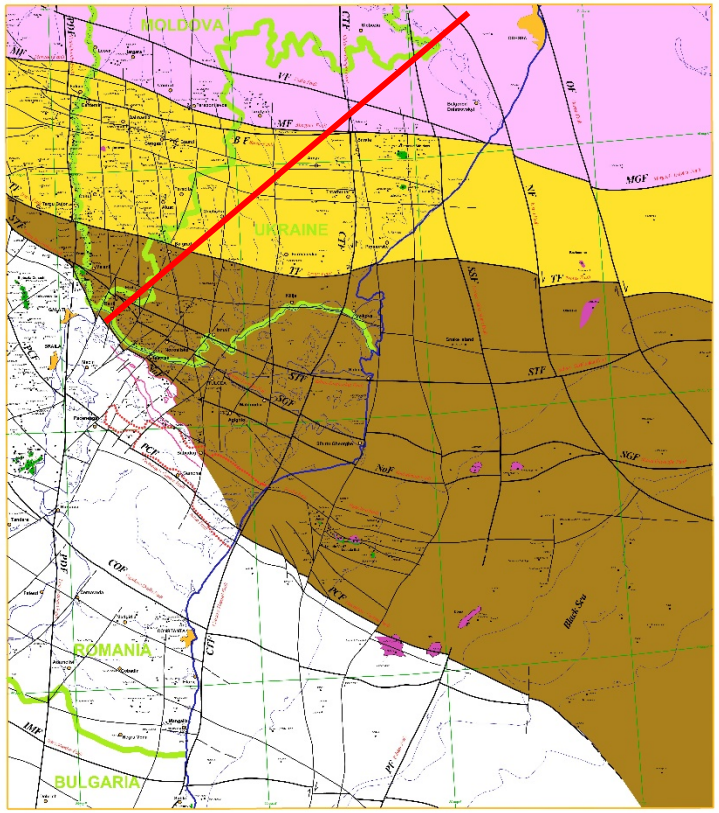
Relationship between Baltica and Scythia – Orenburg to Solletsck

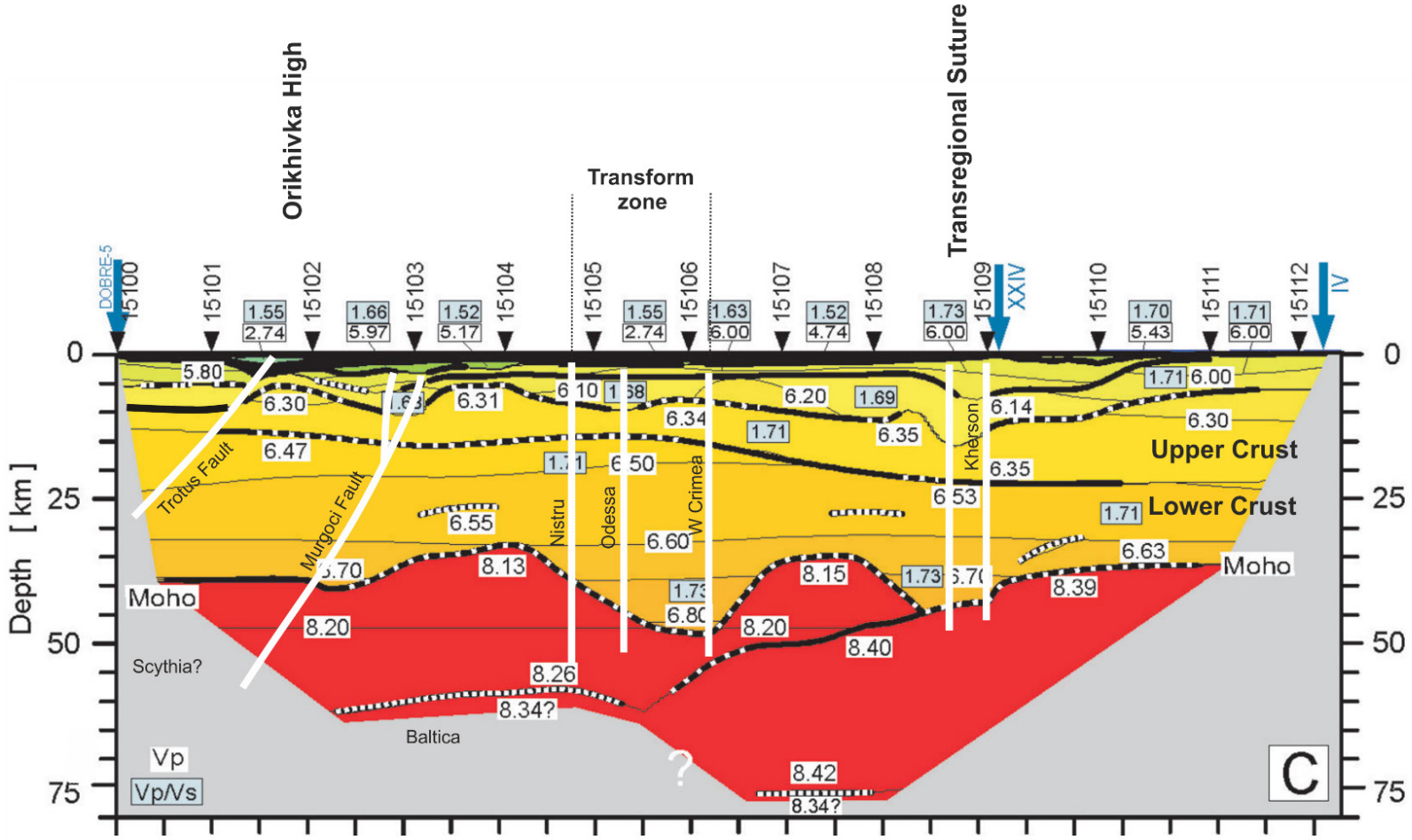


Modified from Kheraskova et al 2015

Presenter's notes: In the eastern sector of the Scythia micro-Plate, the obduction implies only the sedimentary cover of both Baltica and Scythia. There are no data at depth to describe the basement's relationship as we could interpret them in previous slides, in western Scythia .

2-D model of P-wave velocity of the crust and upper mantle DOBRE 4





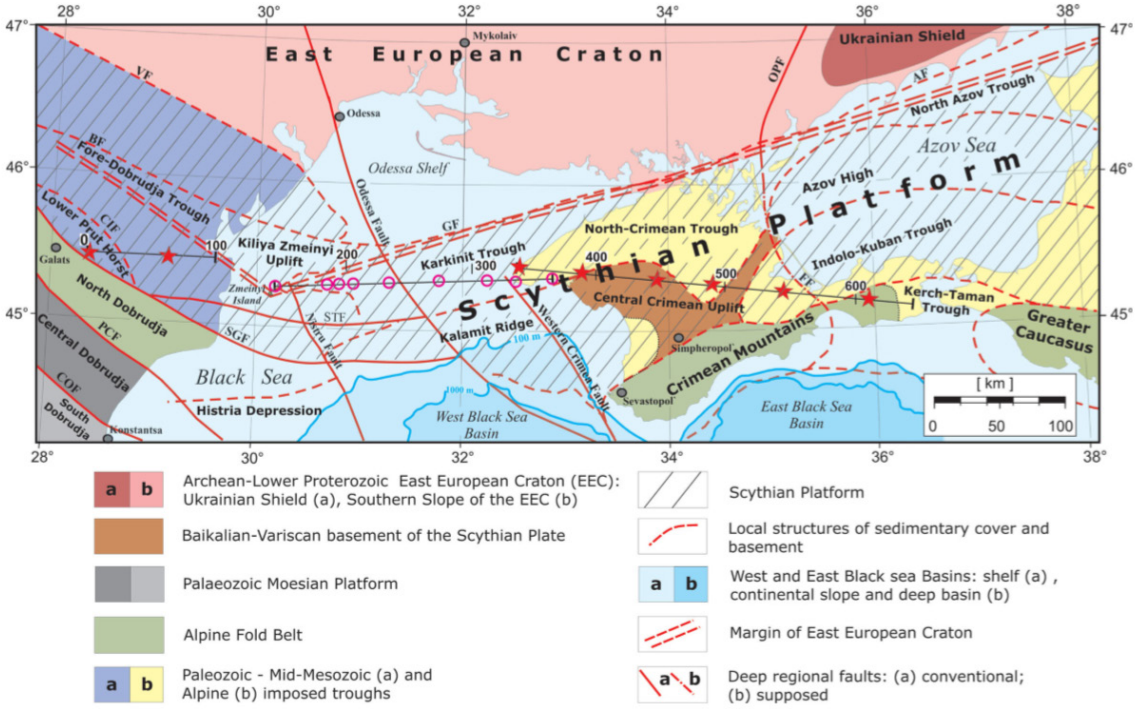
Modified from Starostenko et al 2013 & Kozlenko et al 2013

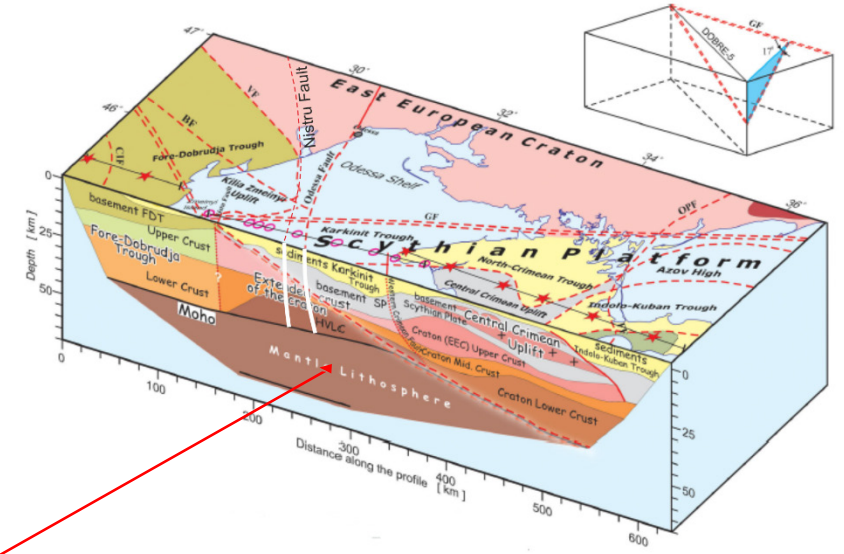
Presenter's notes: Buckling can be explained, inferring both by the higher plasticity of the Lower Crust and by the crossing effect of the major transform zone (Nistru/Odesa/W Crimea faults; see also Daudina and Tari, 2014) and of the Transregional Suture (Smolensk- Kherson; Starostenko et al., 2017). The transform faults would merge into the West Crimea Fault on the southern the Black Sea, Turkish border, as suggested by Tari et al. (2015).

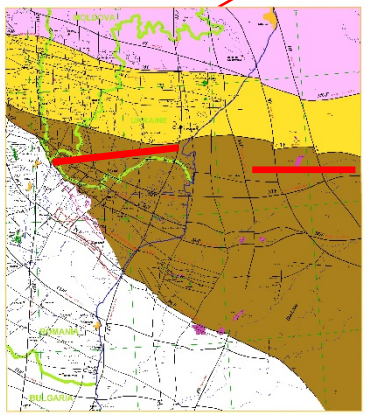
It appears that the West Crimea Fault (Western Moho slope) could reflect the crustal boundary of the Andrusov Ridge while the Nistru Fault is located on the eastern slope of the Serpent Island High. This transform Fault Zone could also explain contrasting rheologies observed east & west of Nistru-Odessa faults (Starostenko et al., 2015).

In our study area we note, at some 35 km depth, the flat surface of Moho between the Trotus and Murgoci Fault Zone projections. Which crystalline basement has Scythia? According to Hazizova (1999), Bush (2014), and Kheraskova et al. (2015), it would be of Riphean amphibolites and greenschists, thus of a Cryogenian age.

Present-day relationship between the Southwestern Baltica and Scythia







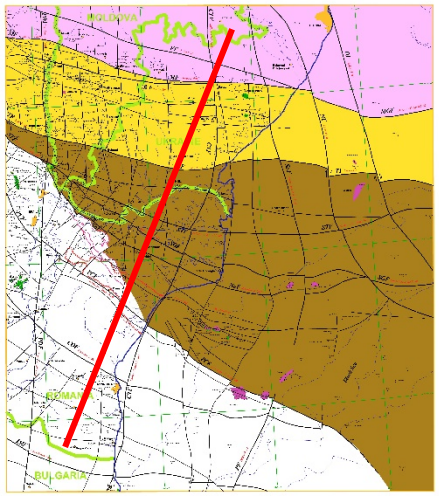
DOBRE V Trace

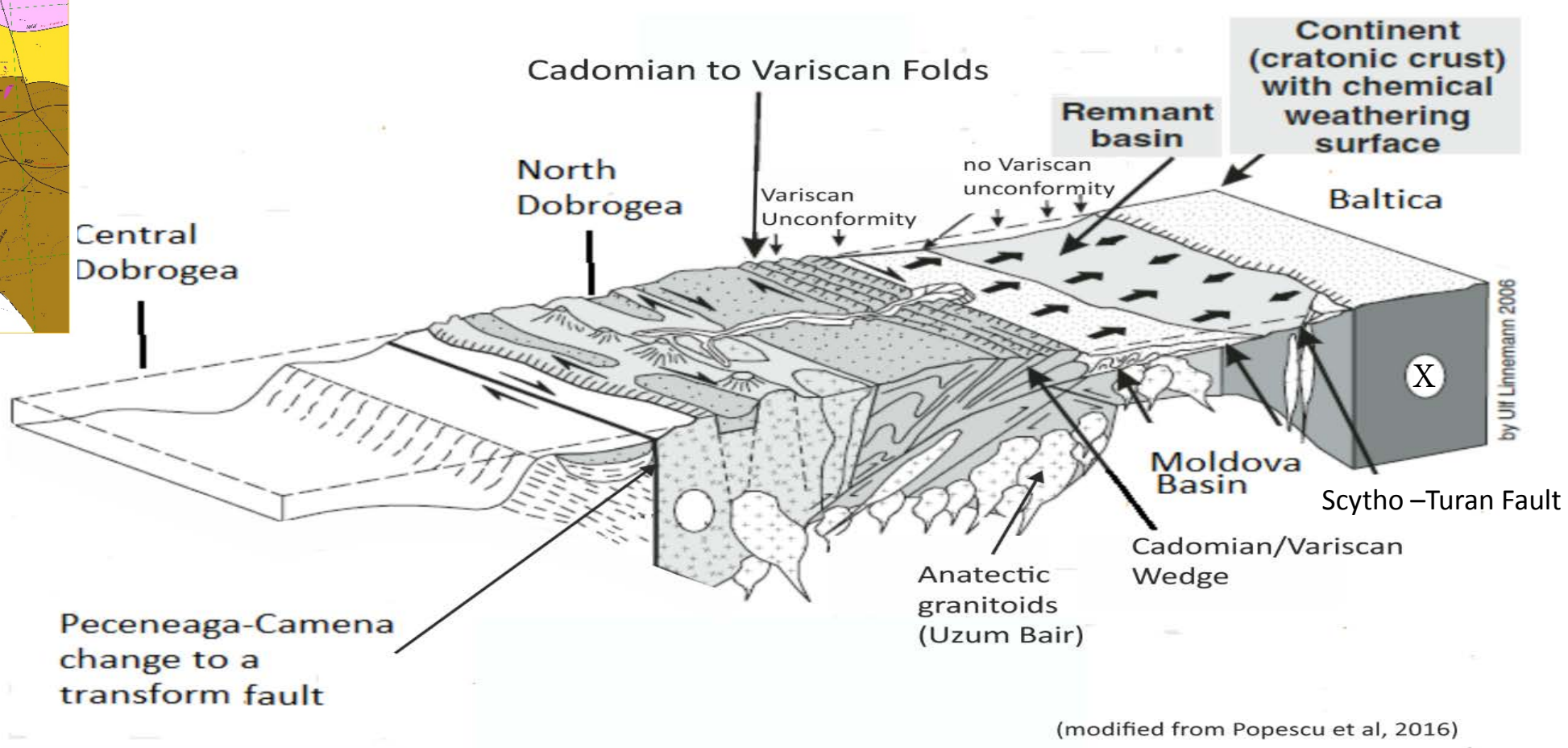
from Starostenko et al 2015, 2017 & Kozlenko et al 2013

Presenter's notes: This is the Starostenco et al. (2015) reconstruction, showing the approximation of the northern extension of Scythia. While they are correct showing the Vaslui Fault (one of faults of the Murgoci Fault Zone) as the limit of firm EEC basement, they are incorrect on the Bistrita (Murgoci) Fault trace. In addition there is no evidence of the extension of Scythia up to the Vaslui Fault, as demonstrated with preceding slides.
Serpent Island is important because it marks the trace of Serpent Island Fault (here Nistru, from Morosan, 2007) anastomosing in the Nistru Transform Fault and a marked change in the basement structure west of it, including superposed Scythian and Baltican basements.

Conceptual Model of the Cadomian/Caledonian/Variscan Collision of Scythia to South Baltica

(adapted from Linneman et al 2007)





Presenter's notes: This is adapted from a retro arc model (Cadomian Retro arc basin in Germany about 545-540 Ma[Linnemann et al., 2007]). It is tought that it could be considered a model for the back arc configuration in our region, some 520 Ma. It has peculiar similitudes with the couple Central Dobrogea and Tulcea Unit (North Dobrogea). The Peceneaga-Camena Crustal Fault, bounding south the Nord Dobrogea could had been there since the Ediacaran.
The Cadomian orogeny acted later here (Caledonian as well!). The mobile Moldova basin/NDD area was subject to the Caledonian contraction around 410-400Ma in the Early Devonian.
Note last Variscan push left a continuous Upper Pz sedimentary sequence in front of the Trotus Line …e.g. Variscan foreland.

Conclusion

- Before the beginning of the Phanerozoic, eastern Scythia micro-plate collided with southern Baltica during the Cadomian-Timanian contractions (Bush, 2014; Kheraskova et al., 2015) . The western Scythia micro-plate appears to have collided later, around 520 Ma as shown by the age of deformations in the Moldova Basin (Popescu et al., 2016).
- In the Early Phanerozoic time, the northern border of eastern Scythia was again deformed by Caledonian movements overprinting the Cadomian folds; in the southern area of Scythia, up to Peceneaga-Camena Fault, developed a retroforeland basin in the Tulcea Unit.
- Some of these slightly metamorphosed folds crop out sparsely in the N Dobrogea Highland; the age of formations was recently reconsidered with the help of Zr-Pb data (Balintoni & Balica, 2016; Seghedi et al., 2016), requiring more field investigations and structural re-interpretations.
- The Nistru Transform Fault put in contact the thin Paleozoic cover of Baltica in a northwestern compartment with the thicker one belonging to the Dniester Graben in the southeast, through a 4000m offset fault escarpment. We believe this fault has a major role in the shaping of the Paleozoic eastern Scythia and later on, together with the en echelon Odessa and W Crimea transforms, in the later Cretaceous opening (e.g., Schmid et al., 2008; Tari et al., 2015) of Black Sea.
- Widespread evidence of the Late Paleozoic deformations has been embodied in the recognizable front of Variscan deformations from Romania to Crimea. This thrust line, in front of a string of uplifted blocks has several segment denominations: Romania: Trotus Fault; Moldova: Vadul lui Isac-Vulcanesti; Ukraine: Bolgrad-Kilija; Black Sea: N Crimea Suture (Yudin, 2012).
- In Romania the Trotus Fault was re-activated until the Early Sarmatian as a sinistral strike slip. The slip stops in front of the sub-meridian crustal Prut-Danube Fault via a splay of vertical, negative fault structures (Matenco et al., 2007).
- In the Moldova/Ukraine borderland, the Izmail-Cahul line would better describe the Variscan-Cimmerian front (e.g., Sliusar 1984), but its continuation in Romania appears to be a sub-vertical version “accident cross” of a Permo-Triassic half-graben. More research is required in this area.