DOES VRANCEA NAPPE GO WEST?

Bogdan M. Popescu

e-mail: bmpopescu@gmail.com

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Abstract. The presence of the Vrancea Nappe beneath the Dacian Basin synkinematic and post-tectonic cover from the SE Carpathians has been challenged for a while back. Available subsurface data shows its presence can be interpreted in the Bend Zone and eastern Getian Basin. It is proposed that the Vrancea Nappe is present in the Bend Zone, in a halfwindow west of the Teleajen Valley and up to Dâmboviţa Fault(DF), which is here preliminarily called Dâmboviţa Halfwindow. The Vrancea Nappe frontal line is tentatively outlined on some 60 km length to the Getian Basin also based on the outwards disappearing of the pre-Burdigalian deposits in the Pericarpathian Nappe. In addition, the subsurface information down to the drilled Oligocene sequences shows the facies individuality of this nappe as compared with the inwards Tarcău Nappe one.

Key words: Eastern Carpathians, Getian Basin, Vrancea Nappe, Bend Zone, Vrancea Line, Petroleum System

1. INTRODUCTION

The identification of the Vrancea Nappe in the Bend Zone is a matter of keen consequence for the petroleum systems of the Eastern Carpathians. Several researchers (e.g., Paraschiv & Olteanu, 1968, Pătruţ *et al.*, 1973, Ştefănescu *et al.*, 1988, 2000, Dicea 1996, Mihai 2012, Schleder *et al.*, 2019) suspected its presence without developing assumptions on its structure and mappable extension in the western end of the Bend Zone. The Vrancea Nappe, or Unit, and the Vrancea Line are known northeastwards in the Central and Northern East Carpathians sectors, typically developed in several halfwindows: Vrancea, Oituz, Bistriţa, Putna. Then, from the Suceava Valley north, in Ukraine, it crops-out in another large halfwindow (Putna-Przemysl) of the Borislav-Pokuttia Nappe, disappearing farthest north, beneath the Skiba/Skole Nappe advancement in Poland.

This note aims to discuss the presence of the Vrancea Unit southwards, in the Bend Zone, in a halfwindow extending from the west of the Cricovul Sărat Valley and up to Dâmboviţa Fault (DF), preliminary called Dâmboviţa Halfwindow.

2. GEOLOGICAL CONTEXT

The Vrancea Nappe - known initially as the Marginal Unit, then the Marginal Folds Nappe - is thrust over by the Tarcău Nappe and overthrust the Pericarpathian Nappe also known as the Miocene Zone, the Miocene-Pliocene Zone or as the Diapir Fold Zone (Fig. 1). The Vrancea Nappe stretches northwards in Ukraine as the Borislav-Pokuttia Nappe and the Pericarpathian Nappe, as the Sambir (Sambor) Nappe, that extends in Poland into the very narrow Zglobice Unit (e.g., Ślączka *et al.*, 2006). In the Bend Zone the Vrancea Unit is concealed beneath the synorogenic and post-tectonic Dacian Basin deposits, except for some piercing diapir folds (Fig. 2b).

In Romania, the frontal Pericarpathian Line, is the boundary between the Carpathian Thrust and Fold Belt and its foreland. This major line was followed in surface down to the Trotuş Valley, then it disappears southwards beneath the Dacian Basin unconformity being interpreted on seismic and drilling data further south and west, up to the Timoc Fault (TiF). The Pericarpathian Nappe (or the Burdigalian Wedge, Krézsek *et al.*, 2013) in the Getian Basin is devoid of pre-Burdigalian deposits and shall serve as an anchor of the discussion on the related Vrancea Line trace.

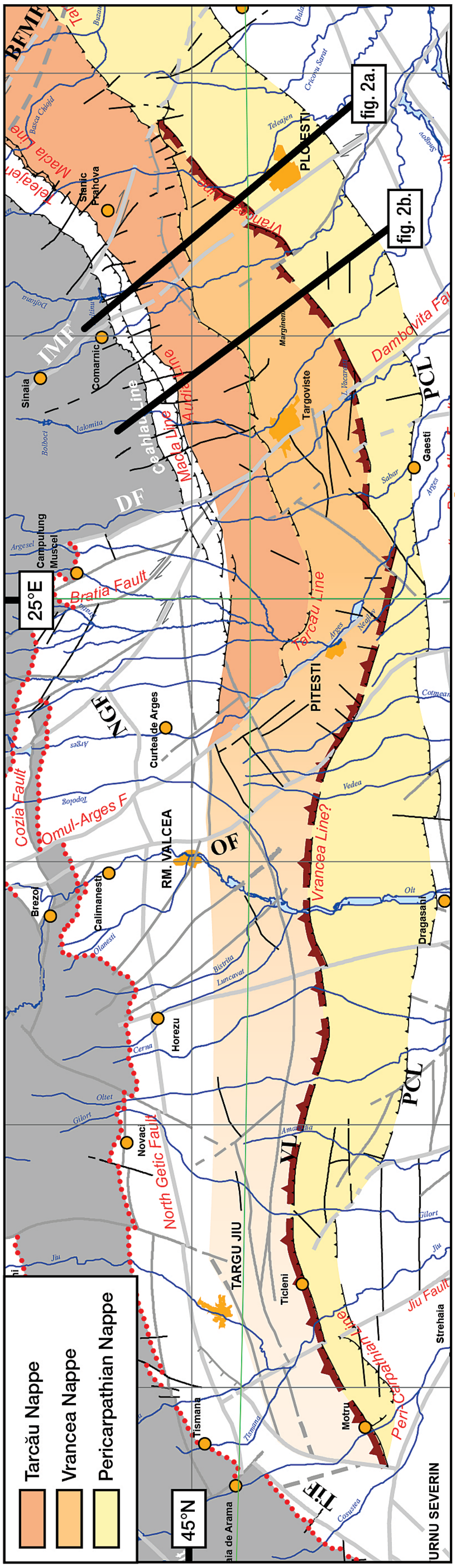

Fig. 1. General structural framework of the Diapir Fold Zone and Getian Basin from the Cricovul Sărat (E) to the Motru (W) valleys. DF-Dambovita Fault, IMF-Intramoesian Fault, NGF-North Getian Fault, OF-Olt fault, PCL-Pericarpathian Line, TiF-Timoc Fault.

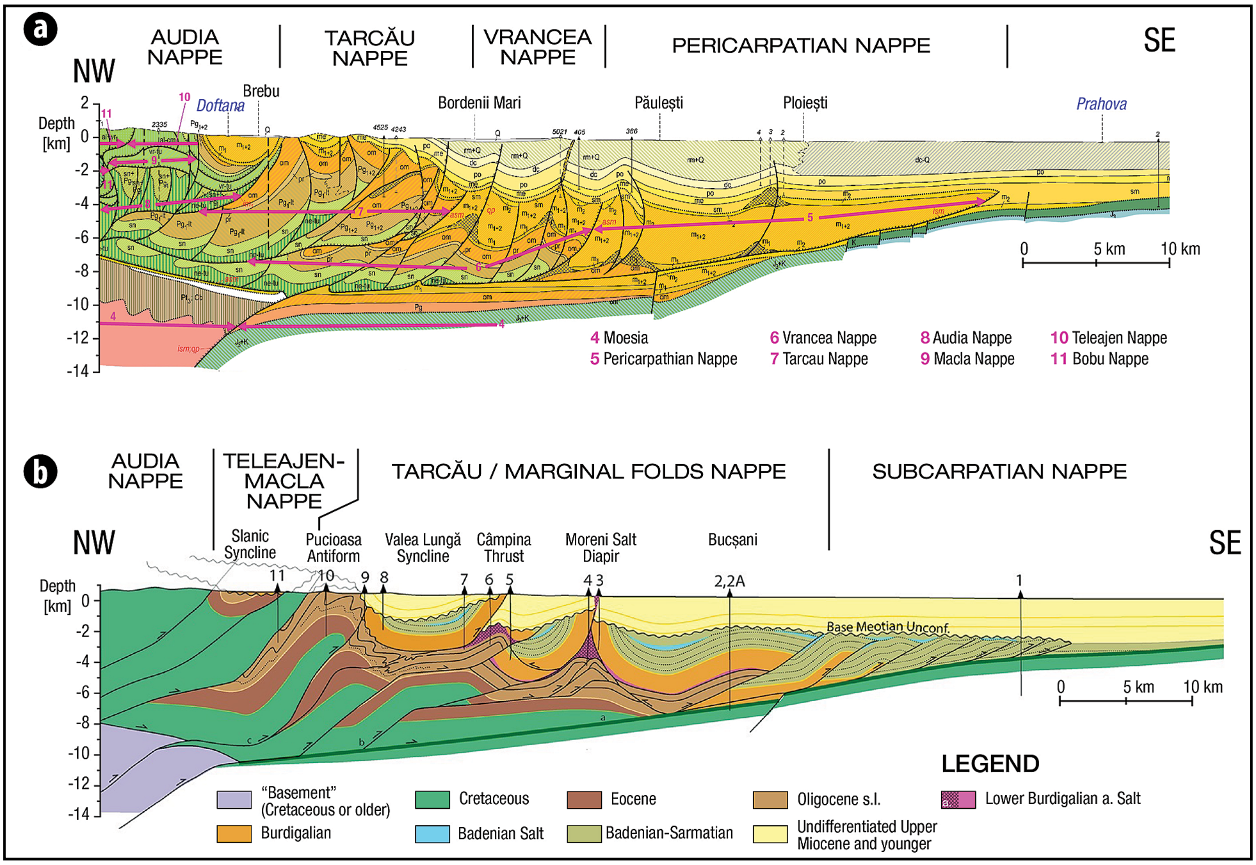

Fig. 2. Proposed tectonic position and structure for the Vrancea and Pericarpathian units. (Adapted or redrawn after **a**. Ștefănescu *et al.*, 1988, **b**. Schleder *et al.*, 2019).

3. VRANCEA UNIT IN THE BEND ZONE AND BEYOND

The supporting proposition for the presence of the Vrancea Nappe, in the Bend Zone, is related to the occurrences, south of the Tarcău Line, of some peculiar structures known from the Central and Northern (including Ukrainian Eastern Carpathians) such as antiforms and duplexes and, not least, the remarkable richness of the petroleum system (Fig. 3) related to these structural and basin facial areas in the whole Eastern Carpathians. Moreover, and outstanding, the Oligocene was not encountered south of the proposed Vrancea Unit front line, in the Pericarpathian Unit or the Getic Basin, westwards (e.g., cross-sections of Pătruț *et al.*, 1973 or of Schleder *et al.*, 2019) similar to the correlatable Sambir Nappe in Ukraine. Further north, we interpret the small area outcrops of the pre-Burdigalian in the Pietricica Unit of the Pericarpathian Nappe, in Central and Northern Eastern Carpathians in Romania, as olistoplaques or olistostromes belonging to the Gura Șoimului Formation. There is no information on older than Oligocene deposits in the Vrancea Unit of the Bend Zone although they are likely to exist at high depths, not yet reached by drilling.

In the Bend Zone, the Vrancea Nappe thrust structures include the additional overprint of Wallachian backthrusts and re-alignments of structures with outcropping early Miocene salt walls (i.e., Moreni-Băicoi alignment). In addition, there is a differentiation in the Oligocene lithostratigraphy in the subsurface (Man 2009) with respect to the outcropping Tarcău Nappe (Figs. 1, 2).

There is a consensus that the Vrancea Nappe structure was (Fig. 3) finalized in the mid-late Sarmatian Moldavidian "phase" deformations. The out-of-sequence Wallachian deformations in the proposed area from the Bend Zone, Vrancea Unit, together with the Tarcău Unit was brought up to the exhumation stage and erosion of fold crests. New, syn-depositional folding, diapirism and thrusting affected the entire sedimentary sequence, regardless of whether they belong to the nappe system, or their mutual post-kinematic cover of Late Miocene-Quaternary deposits (e.g., Ștefănescu *et al.*, 2000). It eventually registered, in the Bend Zone, a lateral translation of about 22 km (Schleder *et al.*, 2019).

In the Dâmbovița Halfwindow, the recognizable relationship between the Vrancea Nappe with the hindward Tarcău Line was mapped in the subsurface on certain length by seismic and wells drilled for oil in accumulations such as Colibași, Sotânga (Batistatu 1998) or Provița-Runcu (Man 2009) that identified high angle imbrications in the Tarcău Nappe, with observed offsets up to 2 km of the same age producing sands. A strong tendency of backthrusting, was well noticed in the Tarcău Nappe (e.g., Ștefănescu *et al.*, 1993) on the Buzau Valley.

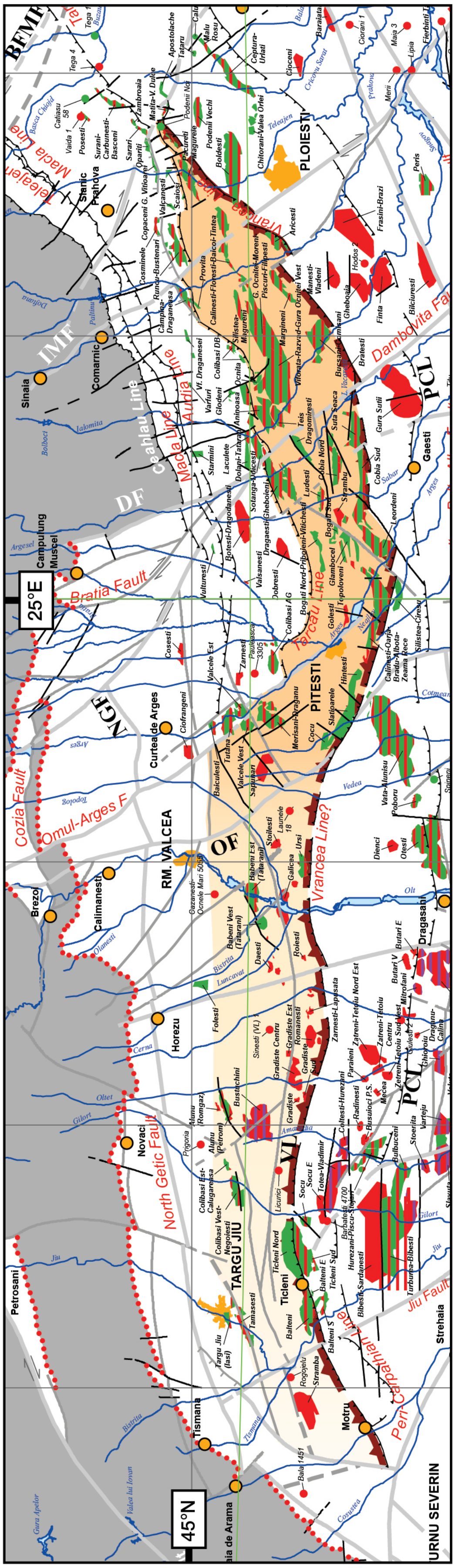

Fig. 3. The Vrancea Nappe and hydrocarbon accumulations in Eastern and Southern Carpathians. DF- Dambovita Fault, IMF-Intramoesian Fault, NGF-North Getian Fault, OF-Olt fault, PCL-Pericarpathian Line, TiF-Timoc Fault (after Popescu *et al.*, 2020).

The horizontal displacement of the Tarcău Nappe is estimated to be only some 10 km in the Bend Zone (Ștefănescu *et al.*, 1988), a significant difference compared with the more than 25 km detected in the Central and Northern Eastern Carpathians (Băncilă 1958, Dicea 1995). Part of this difference can be assigned to the backthrusting during the Pliocene-Quaternary.

The Vrancea frontal line was traced at the base of the lowest imbrications containing Oligocene deposits (brown in Figs. 2, 3). The presumed Vrancea Line was drawn eastwards from the Dâmbovița crustal fault, in front of the Brătești, Bucşani, Mărgineni, Ariceşti, Tintea, Păcureți, Matița structures (Fig.3). East of the Teleajen and Cricovul Sarat Valley it is difficult to interpret this line trace northeastwards because of poor seismic available for below the Dacian Basin cover. For instance, on the Buzau Valley, the closest well-exposed section of the Eastern Carpathians, downstream of Tarcău Unit imbrications, the possible contact with the Vrancea and/or Pericarpathian units is covered by the Upper Miocene-Pliocene of the Salcia and Cărbuneşti piggybacks. However, north-eastwards, on the Slănicul de Buzau Valley it is interpreted, based on the Serini *et al.* (1999), the presence of the Vrancea Nappe in some 5 km width tectonic Mânzăleşti Window

In the Getian Basin, westward of the DF, the Vrancea Line could be construed at least some 50 km in length, in front of the diapir fold structures, up to about the Pitești meridian, based on the disappearing, in the Pericarpathian imbrications, of the pre-Burdigalian deposits like in the Diapir Fold Zone (e.g., Pătruţ *et al.*, 1973). Furthermore, it is proposed that westwards of Pitești, the Vrancea Line merges into the Paleogene (or Oligocene Line of petroleum industry reports) up to the TiF Fault (Figs. 1,3).

Northwards, it is supposed that the high angle Tarcău Line can be identified at some 30 km distance in the subsurface west of the Dâmbovița Fault, in the Getian Basin (Krézsek *et al.*, 2013). The relationship of the Vrancea and Tarcău nappes is not well understood in the Getian Basin areal, mainly west of the Omul-Argeş and Olt fault systems (Fig. 1), where a major structural change might take place in the area of Drăganu NW-SE transtensional pull-apart basin where all the inner Eastern Carpathian nappe package collapsed due the ongoing orogen partition straining (Krézsek *et al.*, 2013) along the North Getic Fault (NGF).

4. PETROLEUM SYSTEM

The Paleogene Petroleum Subsystem covering the proposed Vrancea Nappe development in the Bend Zone is the country's most prolific and has a twice higher concentration of reserves per km^2 (Paraschiv & Olteanu 1970, Pătruţ *et al.*, 1973, Harms & Brady 1993) compared with the Northern Eastern Carpathians one. This is due to more effective local trapping and massive re-migration prompted by the Wallachian deformations that lead to the apparition of a final critical moment at around 2.5-1 Ma. Schleder *et al.*, (2019) estimated the in-place resources in the whole Bend Zone are 4-5 Bboe of which I estimate that about 4 Bboe belong to the proposed Vrancea Nappe designated area in the Dambovita Halfwindow (Fig. 3).

5. CONCLUSIONS

If this interpretation proves correct, a first conclusion is that the in-sequence Vrancea Nappe is present in the Getian Basin, then in front of the Tarcău Nappe in the Bend Zone, the Central and Northern Eastern Carpathians, up to its equivalent in Ukraine but is unknown in the Polish Carpathians. Between the Dâmbovița and Cricovul Sarat valleys its positioning can be provisionally called the Dâmbovița Halfwindow until further research defines its actual extension west of the Dâmbovița Valley.

Another conclusion is that, unlike Tarcău and Vrancea nappes, as well as in the Măgirești-Perchiu Unit, the Pericarpathian Nappe is devoid of Oligocene deposits in Romania (e.g., in the Bend Zone, Schleder *et al*., 2019, Getic Basin, Roşu 2005, both units, Munteanu *et al.*, 2014) as it is in the equivalent Sambir (or Sambor) Nappe in Ukraine and the Zglobice Nappe in Poland (Koltun *et al.*, 1998, Oszczypko *et al.*, 2006).

Finally, its petroleum system has similar, intelligible attributes and development in the Eastern and Southern Carpathians re-emphasizing its prominent role in the generation of the largest in the country hydrocarbon accumulations same as in the Ukraine Boreslav-Pokuttia Petroleum System (Popadyuk *et al.*, 2006, Ślączka *et al.*, 2006).

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