B. ACTIVITIES RELATED TO DATA SYNTESIS

At this stage we focused on the following objective:

2. ANALYSIS AND CRITICAL DISCUSSION OF THE CURRENT MODELS ASSOCIATED TO GEODYNAMIC EVOLUTION OF THE EAST CARPATHIANS IN CONNEXION WITH MIOCENE-QUATERNARY MAGMATIC ACTIVITY (1).

2.1. GEODYNAMIC MODELS FOR THE EAST CARPATHIANS (1)

Geodynamic reconstructions in the Carpathian-Pannonian Region (CPR) are the result of manifold geological and geophysical approach. The progress in the geodynamic reconstructions is reflected in the succesive models realized up to now. The initial models were generated by using mainly geological information, whereas the recent ones includes increased petrological and geophysical data. The first models discussed geosynclinal theory. An important step in the knowledge was the introduction of the global theory of plate tectonic developed at the beginning of the 70th (ex. Dickinson, 1971). According to this new theory, the early geodynamic models for the CPR adopted the model of circum-Pacific areas, so that all the mountain areas at the border of European Plate were interpreted as a result of the collision between an “island arc” and the European continent. “Island arc” were defined by their characteristic structural elements: (1) oceanic plate; (2) through; (3) folded basement; (4) calc-alkaline magmatic arc; (5) a backarc basin. The items (3), (4) and (5) have been considered in some models characteristic for CPR, at that time assimilated as an arc-type, or even “island arc” type (ex. Bleahu et al., 1973; Rădulescu, Săndulescu, 1973; Boccaletti et al., 1973) (Fig. 10).

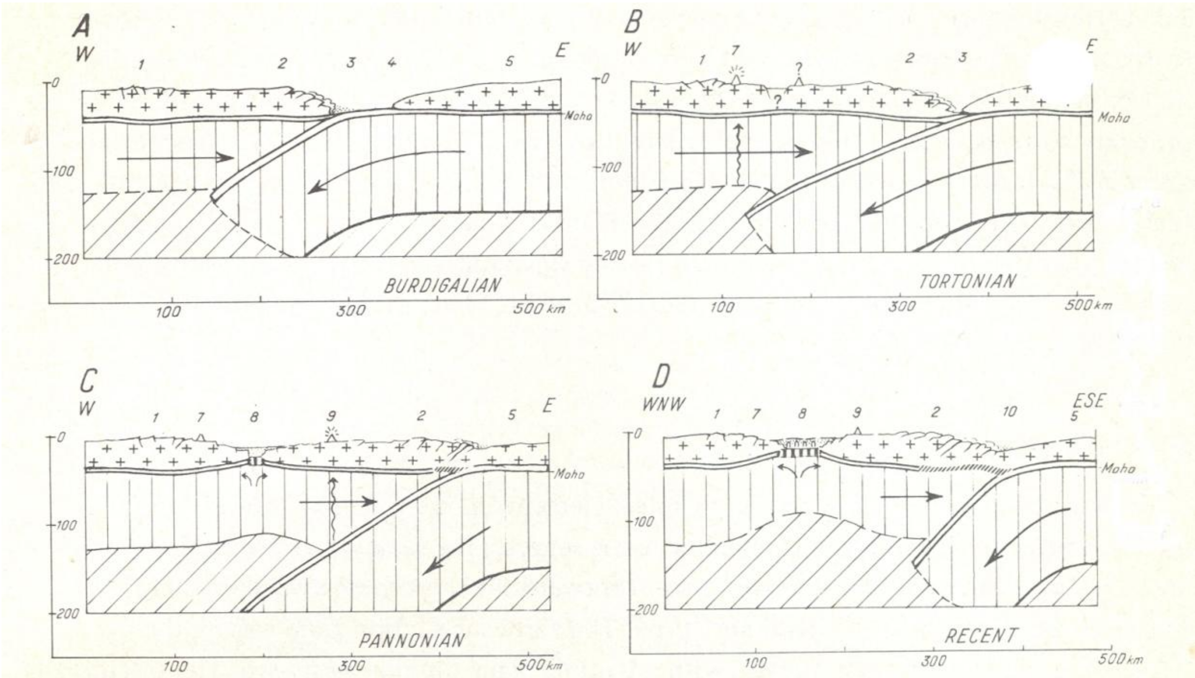

Fig. 10. – Interpretative geological cross-sections along the East Carpathians (acc. Boccaletti et al., 1973) that suggests the tectonic plate model for Burdigalian-recent times. Symbols: crosses: continetal crust; vertical lines: upper mantle; oblique lines: asthenosfere; 1: Apuseni; 2: East Carpathians; 3: through; 4: oceanic crust; 5: East Carpathian platform; 7: calc-alkaline rocks in Apuseni Mts.; 8: Transilvaniya basin as back-arc type; 9. calc-alkaline rocks in the East Carpathians (Călimani-Gurghiu-Harghita volcanic chain); 10: Areas with active sedimentation and negative Bouguer anomaly.

The following research studies evolved following two shemes: tectonic reconstruction (1) and reconstruction of magmatic processes (2) in this way enhansing the previous simplistic models with complex models that highlight the special pecularities of the Alpine-Carpathian-Hymalaian belt, as difeent from the circumpacific one (e.g. Prelevic, Seghedi, 2013).

(1) The geotectonic reconstructions proved that the basement of the Intra-Carpathian area is composed of several continental blocks (terranes), recognized in the literature as ALCAPA, Tisia (Tisza) and Dacia (e.g., Balla, 1984, Csontos *et al.*, 1992; Schmid et al., 2008). ALCAPA block is situated in the northen part of Pannonian Basin, since Tisia and Dacia are sucessively developed in the southern part of the Pannonian Basin, including Apuseni Mts and Transylavania Basin. ALCAPA block is separated by the Tisia block by a major tectonic

dijunction known as Mid- Hungarian Line, active probably since Cretaceous times and a place of numerous tectonic deformations (e.g., Csontos *et al.*, 1992; 2002).

Tisia and Dacia blocks were characterized by a different geologic history during the Mesozoic times, as reflected also by the paleomagnetic data (Pătraşcu *et al.*, 1994). The welded crustal Tisia-Dacia entity is a result of Early-Middle Cretaceous collision, as suggested by the crustal thickening and tectonic nappe generation in Apuseni Mts. (e.g., Balintoni 1997; Dallmeyer *et al.*, 1999), South and East Carpathians (e.g., Săndulescu, 1984, Berza *et al.*, 1994). Geological data suggests that Alcapa and Tisia blocks were derived from the northern margin of Adria (=Apulia) block (e.g., Săndulescu, 1994; Schmidt *et al.*, 2008). Geodynamic evolution of these blocks during the Neogenea implied translation and rotation of the mentioned blocks (e.g., Csontos, 1995; Fodor *et al.*, 1999; Csontos et al., 2002).

Recent tectonic reconstruction of CPR (e.g., Csontos, 1995; Fodor *et al.*, 1999; Huismans *et al.*, 2001; Ustaszewski et al., 2008) suggests that Tisia was translated toward the east during Early-Middle Miocene, along the Alcapa block(Fig. 11).

Such complex tectonic processes generated an impressive active force of movement of the tectonic blocks that implied rotation, collision and acccretion suggesting the probable implication of the subduction accompanied by rotation of the lithospheric blocks presently attched to the European Plate (e.g., Royden, 1988; Săndulescu, 1988; Royden & Burchfiel, 1989; Csontos *et al.*, 1992; Csontos, 1995). Paleomagnetice data prove a clockwise rotation of ~20^{o} during Eocen- EarlyMiocene times (Pătraşcu *et al.*, 1994; Panaiotu, 1998), period when ALCAPA suffered ~30^{o} counterclockwise rotation processes (Márton, Márton, 1996).

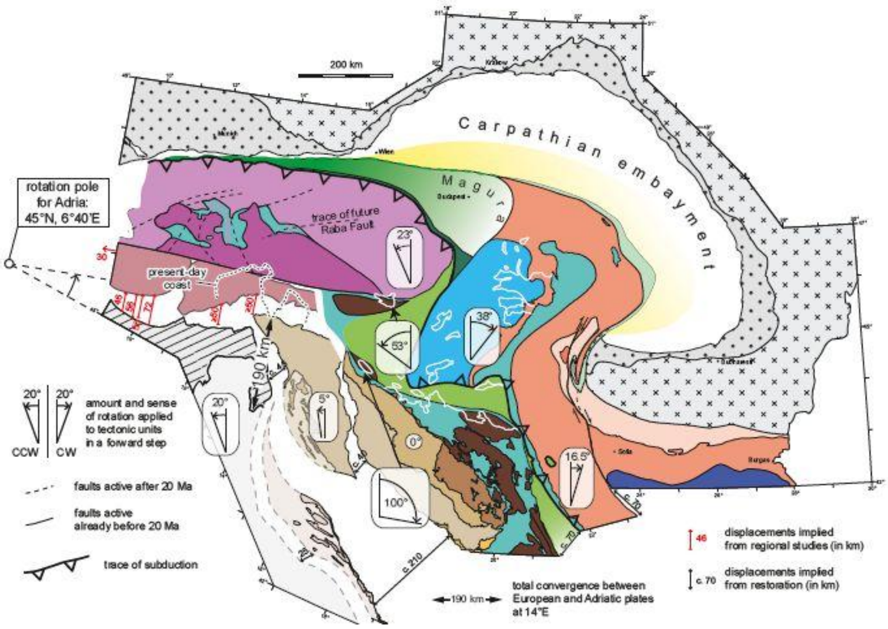

Fig.11. - Restoration of tectonic units in the Alps, Carpathians and Dinarides domain for the Early Miocene. Colours and patterns of tectonic units after Ustaszewski et al. (2008)

Starting to Middle Miocene Tisia and Dacia blocks have been implicated in rapid clockwise rotation (~60^o). These rotations started at ~ 14 Ma, diminished at 13 Ma up to 28^o and stoped at ~12 Ma (Panaiotu, 1998, 1999). Between 14-12 Ma, only the nord-estern part of ALCAPA was rotated, as couterclockwise between 50^o-20^o (Panaiotu, 1998, Márton *et al.*, 2000). Important clockwise rotation of Tisia (along Dacia) (Apuseni Mts.) generated during Badenian – Early Pannonian times, at the upper crustal levels normal faulting perpendicular on the rotation axis (e.g., Csontos *et al.*, 2002). These faulting was reeponsible for a series of basin generation of core-complex type toward NW-SE direction, visible along the western margin of the Apuseni Mts. (e.g., Royden, 1988; Săndulescu, 1988; Balintoni, Vlad, 1998). Similar graben type basins were detected in the adjacent Pannonian Basin (e.g., Balla, 1984, 1987; Csontos, Nagymarosy, 1998; Csontos et al., 2002). This type of extensional basins is syncronous with major rotation and coincides with sedimentation and magmatic processes strating with Early Badenian (e.g., Balintoni, Vlad, 1998; Roşu *et al.*, 2004; Seghedi *et al.*, 1998, 2004). A schematic geodyanmic evolution is given in the în Fig. 12, after Csontos *et al.* (2002; figura 12c) and Seghedi *et al.* (2004; figura 2b). Upper figure (Csontos *et al.*, 2002) presents the geodynamic situation at the end of major rotations (Panonian times). Lower figure after Seghedi *et al.*, (2004) sugest that the Apuseni Mts. magmatism, as part of Tisia, is in direct connection with the major clockwise rotations between 15.5 - 11 Ma, when the core-complex type extension was associated with graben type basins. In this time interval contemporaneous clac-alkaline magmatic activity developed in the front of Alcapa and Tisia blocks (Pécskay *et al.*, 1995a,b; 2006), in direct conexion with similar type of core complex lithospheric extension as for Tisia (e.g. Nemčok *et al*., 1998; Seghedi *et al*., 1998, 2001, 2004; Seghedi, Downes, 2011). The collision of Tisia block during Upper Miocene (~11 Ma), was considered as a result of the end of subduction retreat with implication of East European Platform megablock (e.g., Csontos, 1995; Maţenco, 1997; Zweigel, 1997).

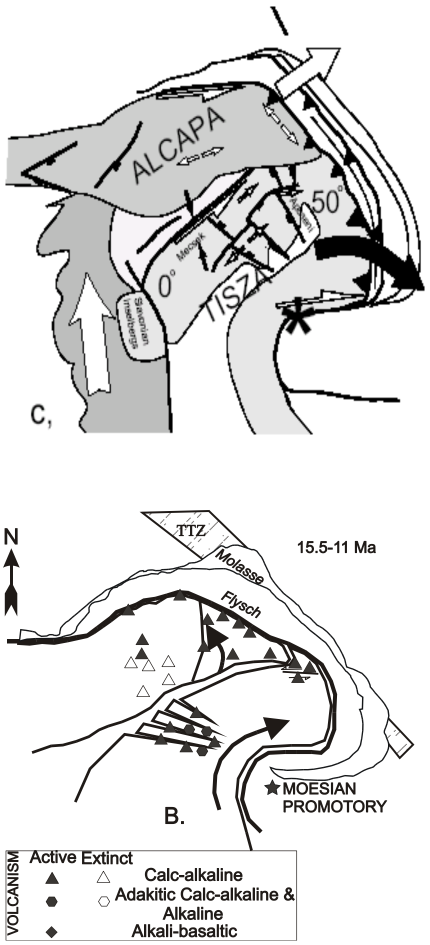

Fig. 12 – Simplified sketches of geodynamic evolution of CPR during Middle-Upper Miocene. This figure reproduces the Fig. 12c from Csontos et al. (2002), suggesting the geodynamic situation resulted during main rotation and translation toward the east (corresponding to Pannonian time). It can be observed the differential rotation processes corresponding to the central and eastern part of Tisia, and also the graben basin opening in the western Apuseni Mts. The lower figure reproduce figure 2b in Seghedi et al. (2004), showing the distribution of the magmatism inside Tisia block (Apuseni Mts.) as being in close relationship with peak rotation period between 15.5 - 11 Ma, concomitant with graben generation. In the same time interval the figure is showing the presence of a contemporaneous calc-alkaline magmatism in the front of Alcapa and Tisia blocks.

Starting to Upper Miocene up to the present times the stress indicators suggests the prevalence of a compresive stess in the southernmost part of the Transylvania basin and its margins toward E-W and NW-SE, followed by an important isostatic uplift (e.g. Huismans *et al*., 2001; Ciulavu *et al*., 2002; Sanders *et al.*, 2002).

Between the mentioned internal blocks and the European platform the Carpathian nappes were compressed with ca. 160-260 km (e.g. Morley, 1996; Behrmann *et al*., 2000; Maţenco et al., 2007; Ustaszewski *et al*., 2008). The contraction processes finished at ca. 11 Ma, but this episode is controversial, since assume subduction processes of a lithospheric material not yet specified.

(b) The studies generated after 1995 concerning the age of the magmatic rocks deny their generation as a result of a direct subduction process, as suggested in the previous studies, taking into account the supposition that the calc-alkaline magmas should be exclusively related with direct subduction processes. In the East Carpathians the volcanism postpone the generation of nappe tectonic units and it is subsequent in Upper miocen-Quaternary times, and in consequence is post-collisional (Mason *et al*., 1996, 1998, Seghedi *et al*., 2011) as generated during contemporaneous extension tectonic processes (Fielitz, Seghedi, 2005). Călimani-Gurghiu-Harghita (CGH) chain represents an important volume of calc-alkaline products joined in its southern part by small volume basaltic Na-alkaline and potassic alkaline associations (Szakács, Seghedi, 1995; Seghedi *et al*., 2004, 2011; Seghedi, Downes, 2011; Lexa et al., 2010). This pattern suggests a continuous N-S rejuvenation in the 11Ma-recent interval (ex. Pécskay *et al*., 2006). In fact all the magmatic occurrences along the East Carpathians including Oaş-Gutâi volcanic areas, “ subvulcanic zone” area(Gröger *et al*., 2008; Pécskay *et al*, 2009) and CGH volcanic chain, strongly evidenced in topography, were generated close to the collision zone of the Carpathians as a result of post-collisional complex tectonic deformations. Such processees facilitated a development of a complex fracture system, extremely active during the magma generation at the surface (Fielitz, Seghedi, 2005). At that time the contemporaneous magmas were acting as a lubricant for tectonic processes (Seghedi, Downes, 2011).

This is a clear demonstration that calc-alkaline magmas were generated not as a direct product of subduction processes, but as a result of adiabatic deccompression processes and lithospheric partial melting during post-collision stage. To generate such kind of magmas it was necessary that the lithospheric mantle to conserve former subduction components (fluids, sediments) (e.g. Seghedi et al., 2004). The presence of a high thermal flux superimposed to CGH volcanic area (e.g., Tari et al, 1999; Demetrescu et al., 2001) is suggestive for acceptance of asthenosphere upwelling, that could be explained by oblique collision and progressive breakoff from N-S, appropriate volcanic activity migration in time and space in the same direction (Mason et al. 1998; Seghedi et al., 1998; Wortel, Spakman, 2000). The volcanic areas of South Harghita and Persani Mts. is the most controversial since of its unusual tectonic setting that produced up to now a numerous geodynamic models (e.g. Cloething et al., 2006; Ismail-Zadeh et al., 2012 şi referinţele incluse) and of its very complex magmatic rock petrology (e.g. Downes et al., 1995; Seghedi et al, 2011) that imply the connexion with Vrancea seismic area.