THE REGION BETWEEN THE SUCEAVA VALLEY AND PUTNA VALLEY (EASTERN CARPATHIANS)

ABSTRACT

The geologic literature regarding Suceava – Putna – Brodina area is quite scarce, consisting of the papers written by Joja (1954, 1955, 1957, 1960, 1965), Joja and Chiriac (1964), Joja *et al*. (1968, 1967, 1978), as well as the papers of Filimon and Albu (1956) and Micu and Constantin (1993) for the Gura-Putnei semi-window.

In this context our mission was to detail the geology of the sector situated north of Putna river and bringing it to a level close of that of the southern areas (Sucevița, Sucevița - Soloneț – Moldovița, Moldovița), updating the information to the actual state of knowledge of the external flysch.

In this purpose, since 1980 thorough terrain survey has been made as well as collecting from separate units of petrographic samples (from which 90 thin sections have been chosen) and of nannoplankton samples (42 samples from which 230 sections were prepared), which were subsequently microscopically analyzed. We have also used data obtained from the geological surveys conducted in the area by S.C. „Geomold" S.A. and by the oil specialists, in this way completing and verifying the geologic model we proposed for the Suceava – Putna – Brodina area.

Following the field survey and the laboratory work, the 1:25000 scale geologic map of the Suceava valley – Putna valley – Brodina valley area (Eastern Carpathians) has been drawn, accomplishing the information on the area's lithostratigraphy, biostratigraphy and tectonics. On the basis of the obtained results some conclusions have been inferred regarding the continuation of the tectonic structures from the investigated region to the southern basins of Sucevița and Moldovița, also multidisciplinary considerations have been made regarding paleontological and paleogeographical aspects as well as a revision of the potentially valuable mineral resources. The text is accompanied by a series of graphic representations and photos (126) that come to fill in the commentaries of the text and justify our conclusions.

LITHOSTATIGRAPHIC CONCLUSIONS

In the Suceava – Putna – Brodina area the deposits belong to two major tectonic units: the Tarcău and Vrancea Nappes that crop out in the Gura-Putnei semi-window.

Tarcău Nappe

The deposits of the Tarcău Nappe crop out to the west and south of the thrusting line that follows on its southern part the right side slope of the Gura Putna brook, on a NE-SW direction, up to the spring area of Glodu brook and then leads towards NNW, beneath the Scorbura and Lomul summits, crossing Suceava valley west of Straja (by „the end of the village").

In this area occur important east-west lithofacial variations, due to geomorphologic modifications of the sedimentation basin that have interfered as a reflex of the geotectonic movements. At the same time are remarked lithologic differentiations in comparison with the southern areas of Sucevița and Moldovița, fact that implies a particular evolution of the sector situated north of Putna River.

Some general features of the area may be observed regarding the maintenance of the sedimentologic uniformity during Senonian – Paleocene, when were formed the detritic carbonatic deposits of the Hangu and Izvor units on the entire area of Tarcău Nappe, as well as an accentuated differentiation of the sedimentation from east to west in the Ypresian –

Bartonian. Later, during Priabonian – Oligocene, a certain homogenization of the sedimentation occurred in the investigated sector, yet the lithofacial differences are maintained on the area of the Tarcău Nappe.

In the Suceava – Putna – Brodina perimeter the lithologic column of the Tarcău Nappe includes deposits of Senonian – Oligocene age.

Senonian – Paleocene

During this period, as already mentioned, on the entire studied area were formed turbiditic, detrito-carbonaceous deposits belonging to the Hangu (Senonian) and Izvor (Paleocene) Units.

Hangu Unit crops out in the Suceava Valley and on its tributaries, as well as on Putna valley and on a series of left tributaries of the latter. It invariably occurs in the front of the Tarcău Nappe and of the Lomul – Scorbura, Bâtca - Glodu, Crucii – Stauina - Sihăstria, Șandru - Măgura Vacii and Solovanu faulted overturned folds. The lower part of the column is cut by the thrust plane of the nappe or by the fault planes of the faulted overturned folds.

The most complete outcrops of the deposits belonging to this unit are offered by Putna river, in the sector between the confluence with Putnișoara and Glodu brooks and at the confluence with Ursoaia brook, and west of the latter, where we have separated the four members identified in Sucevița basin by Ionesi and Florea (1996): the Lower marls with *Chondrites* Member, the Quartz sandstones Member, the Upper marls with *Chondrites* Member and the Sandstone-marl-clayey Member.

The thickness of the unit varies from almost 700 m on Măgura brook, in front of the Crucii – Stauina – Sihăstria faulted overturned fold, up to 500-600 m in Putna valley in front of the Bâtca - Glodu and Crucii – Stauina – Sihăstria faulted overturned fold. The real thickness is difficult to assess because of the high tectonization of the area.

From a lithologic point of view, per ensemble the unit consists of a pelitic-arenitic rhythmic flysch, represented by an alternation of gray-bluish marls and clayey limestones, with traces of *Chondrites* and *Zoophycos*, fractured gray calcareous sandstones, micaceous sandstones with numerous carbonized fragments, yellowish micritic limestones, micro-conglomerates and gray-greenish clays. In the epiclastic deposits the lutitic-siltitic material dominates over the arenitic-ruditic one.

Usually the turbiditic sequences are easily followed and besides those of arenite – arenitic marls - marls, arenite - marls, arenite - shales (clays and marls) (Ionesi and Florea, 1996) sometimes are also found some sequences of micro-rudite (rarely rudite) – arenite – marls type.

Izvor Unit consists almost entirely of arenitic turbidites (Ionesi 1971, 1996; Florea, 1999). The dominant note is given by the existence of a succession of arenitic and pelitic rocks within sequences or poly-strata.

In the Suceava – Putna – Brodina area, the Izvor Unit conformably overlies the Senonian deposits, being identified on the Străjii, Humăriei, Calanceni and Răstoaca Mare brooks (left tributaries of Suceava river), also on Suceava valley, Ascunsul, Ciolotei and Cioloteiaș brooks (right tributaries of Suceava river), Măgura, Sihastru and Jiji brooks (tributaries of Boului brook), Putna valley, Glodu and Ursoaia brooks (left tributaries of Putna). The unit is conformably overlain by the Surcele Unit, except for the Crucii – Stauina – Sihăstria faulted overturned fold, where at its top it is stratigraphically overlain by the deposits of the Straja Unit. The thickness of the unit varies from 110 m on Suceava valley to 150 m on Putna River and Humăriei brook.

The unit consists of turbiditic sequences (quite obvious on Putna River, west of the confluence with Glodu brook), consisting of micro-conglomerate sub-units in base, followed in the middle part by an arenite sequence and at the upper part by silto-lutites. Therefore, in

over 80% of the observed cases may be separated sequences of the *ABCD* type (microrudite – arenite – silt – lutite) and *BCD* type (microrudite – arenite – lutite), or more rarely *BD* (arenite – lutite).

Grasu *et al*. (1988) present in the stratigraphic column of the Izvor Unit the following petrographic types: biosparites and sparites with bioclasts and green rock elements, siltitic micrites, siltitic marls and clayey siltites. Referring to the sedimentation conditions of the unit, the authors relate the low thickness of the sequences with the high frequency of turbidity currents, determined by the accentuated continental slope.

Regarding the source of the terrigenous material Ionesi (1971) indicates a green schists cordillera of foreland type, activated during the Laramic tectonic movements. Grasu *et al*. (1988) comment the complex role of the submerged cordilleras, inferring that on their axial ridges conditions are created for the installation of algae and bryozoan reef biotopes or of sponge biotopes and thus diversifying the basin sedimentary material source, as well as the fact that these cordilleras with an insular development have an active role in the formation of the diapir anticlinoria.

Eocene

During the Eocene the sedimentation has been differentiated in time and space, thus appearing heterotropic facies, due to the installation of a highly dynamic geotectonic regime as compared with the Upper Cretaceous. The mobility of the basin has been expressed through the formation of internal basins, separated by cordilleras and the diversification in this way of the sedimentation domain, through the creation of particular environments in the internal basins and the multiplication of clastic material source areas. The presence of the cordilleras is now unanimously accepted and what still remains in discussion is the position and the tectogenetic moments responsible for their reactivation/raising.

The Eocene litostratigraphic column has at its base the terminal part of the Izvor Unit (Putna beds; Joja *et al*., 1968; Micu, 1979) and ends in the eastern part with the Lucăcești sandstone and *Globigerina* marls Unit and in the west with the Lupoaia Unit.

According to the research data of the detailed field survey in the Suceava – Putna – Brodina area, we have separated the following lithofacies:

- *the Doamna lithofacies* (= the Putna facies; Joja, 1954), that characterizes the eastern part of the Tarcău Nappe, up to a line that follows the front of the Bâtca - Glodu and Străjii faulted overturned folds. The lithologic column of the Doamna lithofacies extends during Ypresian – Bartonian, consisting of the *Surcele, Straja, Sucevița* and *Doamna – Viţeu Units*. The deposits developed in this facies compose the column of the Lomul – Scorbura faulted overturned fold. The upper part of the lithologic succession is cut by the fault planes of the Straja and Bâtca – Glodu faulted overturned folds;

- *the Scorbura – Doamna lithofacies* is developed west of the mentioned line, up to the Falcău – Ștef line. The lithologic column consists of the *Surcele*, *Straja*, *Scorbura*, *Doamna – Viţeu*, *Bisericani* and *Lucăceşti Sandstone and Globigerina marls Units*, of Ypresian – Priabonian age. These deposits enter the constitution of the Straja, Bâtca – Glodu faulted overturned folds and Măgura rasp wedge;

- *the Scorbura – Tazlău lithofacies* has been identified west of the Falcău – Ștef line, up to Brodina valley (Brodina fault). The deposits of this lithofacies belong to the *Surcele*, *Straja*, *Scorbura – Tazlău*, *Plopu* and *Lupoaia Units* and characterize the Ypresian – Priabonian period.

Surcele Unit has a constant development at the base of the Straja Unit, with thicknesses up to 55 m, being present in all the three lithofacieses: Doamna, Scorbura – Doamna and Scorbura - Tazlău.

The separation of this unit in our study area has had as justification the extension of this lithologic unit also to the south of the Putna River, fact that demonstrates that this quartz-arenitic moment did not had a local development characteristic only to our area. This lithologic unit has been described with variable thicknesses, even if not allways separated as a distinctive level, in the Putna - Suceviţa (Joja, 1954; Micu, 1979; Florea, 1999), Râșca-Agapia (Joja, 1952), Voroneţ - Suha Mică - Plotoniţa (Dicea, 1974) and Valea Moldovei (Ionesi, 1961, 1971) regions.

Joja (1952) shows that in the Râșca – Agapia area, over the "Tisaru-like beds" (according to Dumitrescu, 1948, 1952) (= „Straja beds"; according to Joja, 1952) „*stands immediately*" a siliceous sandstone similar to the Kliwa sandstone, that appears with large thicknesses and on large areas in all the internal areas of the Marginal Nappe. It is a fine-grained sandstone, yellowish or yellow-greenish, with medium hardness and with „*numerous green graines, visible with the naked eye*".

Regarding the development of the sandstone levels of Scorbura type in the „Putna facies" (Putna – Putnișoara area), Joja (1954) shows that "*this sandstone* (Scorbura sandstone, n.n.), *that in fact appears as simple beds of a few meters, sometimes even in the Putna facies, has been described by us last year, from the western part of the flysch between Voivodeasa and Suceviţa, on Rusca brook and at Poiana Mese, where it also presents a remarkable development*".

From a lithologic viewpoint, the level is made up of 90% Kliwa-like quartz glauconitic sandstones of yellowish, white or yellowish-brown colour. Within their mass may be rarely observed fragments of green rocks or carbonized remains. It sometimes presents transversal and directional passages towards varieties of weakly calcareous sandstones. These sandstones are usually disposed in massive banks of 1-2 m or even 10-15 m, that sometimes pass directionally into turbiditic rhythms consisting of two terms - arenite and sillto-pelite - where dominates the arenitic fraction.

Straja Unit. Beginning with the sedimentation of this formation, the differentiation of the sedimentation conditions on the area of the Tarcău Nappe becomes obvious.

In the eastern part, in the Doamna lithofacies, the unit has a typical development, according to the stratotype, consisting of an alternation of clays and siltstones with quartz glauconitic sandstones, limestones, silicolites and spongolitic gaizes in thin beds, with a characteristic red-tiled color at the surface. The coarse-grained quartz sandstone intercalations with thickness of 0.5-0.8 m have low frequencies. The outcrop thickness of the unit is up to 80 m.

In the Scorbura – Doamna lithofacies the lithologic aspect changes, being different to both the eastern and western areas. The lithologic column of the unit is reduced to a rock packet of 10-40 m, consisting of an alternation of silto-lutites and arenites, disposed in 5-15 cm beds.

Westwards, in the area of Scorbura – Tazlău lithofacies, the unit has a stratigraphic thickness of 70 m, revealing a dominantly arenitic character, as compared to the situation from the front of the Tarcău Unit. The arenitic-silto-lutitic material ratio is of 1:1.

This facies variation is consistent with the fact that in the west of the Suceava – Putna – Brodina area the eastern-type sedimentation has alternated with the western-type, which denotes that this is an area of interference of the sedimentologic factors that controlled the sedimentation in the western and eastern basins.

Suceviţa Unit crops out only in the eastern part of the area, entering the constitution of the Lomul – Scorbura faulted overturned fold. It crops out north of Suceava river, on Straja brook and at the springs of the Calanceni brook and south of Suceava River, on Boului brook. It conformably overlies the Straja Unit and is overlain, also conformably, by the Doamna – Viţeu Unit.

Lithologically, it is made of an alternation of quartz sandstones, sandstones with calcareous cement, with hieroglyphs, arenitic limestones, bioclastic limestones, clays and gray or greenish marls. The Sucevița deposits represent an arenitic-calcareous–clayey flysch, characteristic in our study area only to the eastern part of the Tarcău Nappe. In the western area, the basin sedimentation conditions were radically changed and consequently the lithology is totally different. The tectonic situation and the covering degree of the terrain in the outcropping area of the Sucevița Unit did not allow supplementary detailing of the stratigraphic column.

Scorbura Unit. The first information regarding the development in the Suceava valley of the deposits overlying the Straja Unit, in a peculiar arenitic facies, were brought by Joja (1954, 1955, 1957). Yet, what Joja did not correctly realize was the fact that the maximum extension of these rock levels, named by him *Scorbura sandstones*, is not characteristic for Scorbura Hill, but for the more western alignments of Bâtca Hill - La Strungi – Glodu Hill and Culmea Cârmaci – Stauina Hills.

The places where the stratigraphic column of the unit is completely opened, allowing a detailed lithologic description as well as the separation of the contacts with the bed and the roof deposits, are situated in the extreme areas, to the north – in Suceava valley, in the Caraula sector and to the south - on the Glodu brook and in Putna valley (in the sector between the confluences of Glodu and Icoana brooks). The representative section is that from Suceava valley, Caraula sector.

In the Caraula sector, over the Straja Unit follows on a stratigraphic thickness of almost 370 m a succession consisting of over 90% of sandstones beds and metric banks, in which the silto-lutitic intercalations are reduced, representing less than 10% of the lithologic column. The monotony is interrupted only at the upper part by an intercalation of almost 25 m of fine-grained greenish sandstones and silicolites. Over this beds follow again, up to the Doamna limestone, the same type of sandstones. It is worth mentioning that the stratigraphic relations between the bed deposits (Straja Unit) and the roof ones (Doamna – Vițeu Unit) are of continuity and the contacts with these deposits are very clear in the open outcrops.

The lithologic situations mapped in the Caraula sector and southwards, on Putna valley and Glodu brook have justified the separation of two members: the *Caraula Member* and the *Calanceni Member*.

The *Caraula Member* has been separated in the section of the Caraula sector and then identified on Putna valley, Glodu, Calanceni and Răstoaca Mare brooks. The total stratigraphic thickness varies in the range 245 – 280 m, on Glodu brook and in Caraula sector, respectively.

The *Calanceni Member* has been separated, as in the case of the lower member, in the profile opened in the Caraula sector. Later it was also identified southwards, on Glodu brook. The thickness of the unit varies from 80 m in the Caraula sector to 120 m on Glodu brook.

Characteristic to this member is the occurrence of 25-35 m thick silicolites, probably representing a recurrent facies similar to the Straja Unit. The recurrence of the Straja type facies is possible, considering that in the Suceava – Putna – Brodina area, even the Straja Unit itself is present as a „siliceous accident" in the arenitic sedimentation of Ypresian – Luteţian, being developed between the Scorbura sandstones from the Surcele Unit in bed and those from the Scorbura unit in roof.

Doamna – Viţeu Unit maintains its individuality only within the lithofacies of Doamna and Scorbura – Doamna, as on the area of the Scorbura – Tazlău lithofacies it is reduced to some detrito-carbonatic turbiditic sequences, similar to those of the Izvor Unit.

The lithologic context in which the deposits of this unit develop in the Doamna and Scorbura – Doamna lithofacies is close to that of the eastern area of the perimeter of the outcropping area of the Vrancea Nappe in the Gura-Putnei semi-window.

The deposits of the unit crop out in the north, on the left slope of Suceava valley and on a series of Suceava river tributaries (Boului, Calanceni and Răstoaca Mare brooks) and to the south, on Putna valley and on the right tributaries of the Glodu brook. In these conditions we were able to separate both members of the lithologic column: the *Doamna limestone Member* and the *Viţeu sandstone Member*. The outcrop that allowed the separation of the Doamna – Viţeu Unit is opened on Calanceni brook and on the right slope of Suceava river, where the mentioned members could be separated.

The unit distinctions between the two lithofacies stand in the fact that in the Doamna litofacies the unit conformably overlies the Suceviţa Unit, whereas in the Scorbura – Doamna litofacies it overlies the Scorbura Unit. Also, in the area of the Doamna lithofacies, at the upper part it is tectonically cut, while in the Scorbura – Doamna litofacies it is conformably overlain by the red and green clays of the lower Bisericani Unit.

Scorbura – Tazlău Unit. In the investigated perimeter the unit conformably overlies the Straja deposits and is overlain by the Plopu Unit. It crops out at the springs of Bodnar brook (right tributary of Cârmaci river), in Cârmaci summit, on Suceava valley, and on the Ascuns and Ascuncelul brooks.

As in the Moldova basin, in Suceava valley the unit maintains at its lower part the lithofacial characteristics of the middle sector of the area (Scorbura – Doamna lithofacies), whereas at the upper part the deposits are developed in a sandstone-calcareous facies, close to that of the Tazlău Unit. It must be emphasized the fact that Doamna – Viţeu Unit looses its individuality, under the deposits of the Plopu Unit, at the level of the Bartonian being deposited turbiditic sequences, lithologically composed of arenitic sparitic-limestones, silicolitic limestones and silto-lutites.

The sections from Suceava valley (Frasin area) and from the Ascuncelul and Ascuns brooks allowed the separation of the Scorbura – Tazlău Unit in two members: *AscuncelulMember* and *Frasin Member*.

The *Ascuncelul member* conformably overlies the Straja Unit and consists almost entirely of banks and beds of quartz glauconitic sandstones of Scorbura type. The silto-lutitic intercalations are found only at the lower part of the lithologic column and are represented by clays and siltic green marls and in the first sequences a few red clays are also present.

The research on the rock levels litostratigraphically equivalent with the Ascuncelul Member have been conducted by Ionesi (1971) in Moldoviţa basin and by Grasu *et al*. (1988) in Suceviţa and Râşcuţa basins. An interesting matter is the fact that Ionesi (1971) separates over the „ *Straja beds*" in Moldova basin, west of Merţa – Bobeica fault, the „*Suceviţa beds*" which begin with the „*lower level of the Păltinoasa siliceous sandstones*" (= Scorbura sandstone, Joja 1954). This level presents longitudinal lithologic and thickness variations, due to a more pronounced micaceous arenitic input. This level is overlain by the alternation of sandstones and clays specific to Suceviţa area.

At the level of the „ Suceviţa beds" from Moldoviţa basin, in Suceava valley is maintained a facies characteristic to the Scorbura Unit from the Scorbura – Doamna lithofacies, which has been separated as the Ascuncelul Member.

We surveyed *the Frasin Member* in Suceava valley (Frasin area), near the confluence of Suceava river with Ascuncelul brook and Ascuns brook.

The lithostratigraphic level equivalent with the deposits of the Frasin Member is described by Ionesi (1971) in Moldoviţa basin (the Tazlău lithofacies). In this area, over the „Suceviţa beds" are disposed the „Tazlău beds", that form a dominant arenitic series, consisting of grey micaceous sandstones, micaceous sandstones with numerous carbonized fragments, calcareous sandstones, sandy limestones, limestones, green and grey clays, marls and marly limestones with fuchoid traces. The distinctive mark is given by the grey coarse-grained micaceous sandstones, disposed in beds up to 2-3 m thick.

In the Suceava – Putna – Brodina area, the lithologic column of this member has been described in the sections opened near the confluence of Suceava river with Ascuncelul brook and in Suceava valley (Frasin area), where the contacts with the sandstone of the Frasin Member and with the silto-lutites of the Plopu Unit may be very well traced.

The succession in the lithologic column of the member begins with a monotonous alternation of calcareous sandstones and arenitic limestones, with mica on the breaking surfaces, graded sorting, of a grey-purple or sometimes blackish colour, which are disposed in 20-40 cm thick beds, with bottom hieroglyphs, and in some less thick beds with a convolute structure at their upper part. The intercalations of silto-lutitic material are rare and of low thickness (3-10 cm). The deposits are turbiditic, having binary sequences, with arenitic sub-units in base and silto-arenitic at the upper part, or having subordinately ternary sequences of arenite–silt–lutite type.

Over this succession with a thickness of almost 120 m follows, up to beneath the Plopu lutites, turbiditic sequences extended on 45-50 m, similar to those of the Izvor Unit and consisting of microruditic sub-units in base (arenitic sparites with bioclastes), arenitic ones in the central part (calcareous sandstones) and silto-lutitic sub-units at the upper one (silicolitic limestones, marls and siltitic clays).

Plopu-Bisericani Unit has been separated only in the Scorbura – Doamna lithofacies. It crops out on Răstoaca Mare brook, Suceava Valley, Ciolotei and Sihastrului brooks, right tributaries of Glodu brook and on Putna valley. It also crops out on Măgura brook, in the front of the Măgura rasp wedge. The field surveys allowed the separation of two members: the *Strujinoasa red clays Member* and the *Putna green and grey clays Member*.

The *Strujinoasa red clays Member* crops out in the front of the Măgura rasp wedge, on the Cioloteiaş and Sihastru brooks. In the sections from Suceava and Putna valleys these are covered by Quaternary deposits. Lithologically it consists of a banded alternation of red and greenish clays, subordinately grayish, with thin intercalations of gray or gray-greenish quartz glauconitic sandstones with small bottom hieroglyphs. The thickness of this member has been assessed at 10-30 m.

The *Putna green and grey clays Member* crops out in the north on the Răstoaca and Ciolotei brooks and in the south on the Sihastru brook and on Putna valley. The stratigraphic thickness of the deposits is of 120-150 m. It consists of a monotonous alternation of rhythmic sequences of clays and grayish or greenish siltites, with grayish or sometimes greenish quartz glauconitic sandstones and grayish or blackish lithic sandstones, with bottom hieroglyphs and convolute structure at their upper part.

As compared to the lithologic column of the stratotype described on Bisericani brook (left tributary of Bistriţa river) by Athanasiu (1921), reanalyzed by Grasu *et al*. (1988) and the data presented by Ionesi (1971) in Moldova basin, Florea (1999) in Sucevița basin and Bogatu (1999) in the Soloneț – Sucevița – Moldovița area, in the Suceava – Putna – Brodina region the intercalations of arenitic material become much more important, occupying up to 40% of the column. In this context, the Bisericani succession described by us is more similar to what Micu (1981) separates in the external skibes of Sucevița basin as a transition facies, using the name of „ Plopu – Bisericani beds".

Plopu Unit. This unit conformably overlies the Scorbura – Tazlău Unit and supports at the upper part the basal level of the Lucăcești sandstone from the Lupoaia Unit.

In the Suceava – Putna – Brodina area, the deposits of the Plopu Unit are part of the structure of the Crucii – Stauina - Sihăstria and Șandru - Măgura Vacii faulted overturned folds. It was observed on Bodnar brook, in Cârmaciului Summit, Suceava valley and on the Ascuncelul and Ascuns brooks. A complete outcrop of the unit's column is found on Suceava valley, west of the confluence with Ascuns brook, in Șandru - Măgura Vacii faulted overturned fold. Here the contacts with both the lower units (Scorbura - Tazlău) and upper

units (Lupoaia) are clear. To the east, in Crucii – Stauina – Sihăstria faulted overturned fold (right slope of Suceava river), crop out only the lower red and green clays, the upper part being tectonically covered by the deposits of the Șandru - Măgura Vacii faulted overturned fold.

The lithostratigrahic situation from Suceava valley allowed the separation of the *Red and green clays Member*, at the lower part and of the *Green and grayish clays Member* at the upper part.

The *Red and green clays Member* has been separated at the spring of the Bodnar creek, under Cârmaci summit, in Suceava valley (Frasin area), on the Ascuns and Ascuncelul brooks. It is disposed over the turbiditic deposits from the upper part of the Scorbura – Tazlău Unit, on a 10-15 m thickness. It consists of an alternation of red and green clays, with intercalations of greenish quartz sandstones, calcareous sandstones, weekly micaceous sandstones, with graded sorting, disposed in 10-30 cm beds with bottom hieroglyphs.

The *Green and grayish clays Member* conformably follows over the red and green clays, on a 165 m thickness. It conformably supports the Lucăceşti type sandstones from the Lupoaia Unit.

It consists of silto-lutitic sequences of clays and calcareous clays of greenish, grayish-greenish and grayish color that alternate with arenitic sequences of greenish quartz sandstones and grayish calcareous sandstones, disposed in 10-30 cm beds, with bottom hieroglyphs and sometimes with a convolute structure at the upper part.

Lucăceşti sandstone and Globigerina marls Unit. In the Suceava – Putna – Brodina area, the Lucăcești sandstone and *Globigerina* marls Unit is developed in the Scorbura – Doamna lithofacies from the Tarcău Unit, in the terminal part of the Eocene lithostratigraphic column. It has at its base the Bisericani Unit and in the roof the Lower menilites Unit. The relations with the deposits from the lower and upper part are conformable. The unit has been mapped on the Suceava valley, Răstoaca Mare and Ciolotei brooks, the right tributaries of Glodu brook and Putna valley, being part of the lithologic column of the Bâtca – Glodu faulted overturned fold.

The deposits of this unit crop out in complete succession between the green and grayish clays of the Bisericani Unit and the Lingureşti marls, on the Răstoaca creek and Putna River.

On Răstoaca Mare brook (right tributary of Falcău brook) crop out completely the deposits of this unit, with a stratigraphic thickness of 42 m. In this profile are also visible the contacts with the deposits belonging to Putna green and grayish clays Member at the lower part and with the brown marls of Lingureşti (the Compact menilites Member) at the upper part.

Lithologically, they consist of silto-lutitic sequences of grayish, greenish, whitish and banded marls, greenish-grayish clays and yellowish or grayish pelitomorphic limestones, where are intercalated coarse-grained calcareous sandstones with green rock elements, of grayish-olive color, whitish Kliwa-like quartz sandstones and weakly calcareous grey-whitish sandstones. At the upper part the sandstones are coarse-grained, with microruditic aspect, sometimes lens-shaped, with variable thickness in the 10 to 50-60 cm range. At the lower part are individualized 30-60 cm thick beds of Kliwa-like quartz sandstones and calcareous (Lucăcești) sandstones. In this case the Lucăcești sandstone is not disposed as a distinctive level at the upper part of the *Globigerina* marls, but it is present as intercalations at different levels between these ones.

Lupoaia Unit. In the Șandru - Măgura Vacii faulted overturned fold, at the upper part of the Scorbura – Tazlău Unit is developed an „arenitic episode", represented by quartz sandstones of the Lucăcești type.

The development of this facies is not resumed at Suceava valley, because south of the investigated area, in Moldoviţa basin, Ionesi (1971, 1975) describes the Lupoaia Unit west of

Merţa – Bobeica fault, on the area of the Tazlău lithofacies. At the base of the „Lupoaia beds", „a distinct horizon" made up of the Lucăceşti sandstone is developed much more constantly than in the eastern parts, on a 10-30 m thickness. Towards the west, at the level of this „*distinct horizon of the Lucăceşti sandstone" occur facial changes that determine the occurrence of micaceous calcareous sandstones, curbicortical sandstones and green clays, in which persist the siliceous, glauconitic, weakly calcareous sandstones with rare mica flakes, separated by the author as „ Lupoaia beds*". This lithologic context indicates this area as one of interference of the factors controlling the sedimentation within the western Tarcău basin and the eastern Doamna one.

We consider that between the Falcău – Ştef line at east and Brodina line in west, in the Suceava basin, there is an area of continuity of the one described as an inteference area of the eastern and western facies, separated also by Ionesi (1971) to the south, between the Merţa – Bobeica fault at east and Dobra – Lupoaia fault at west (Moldoviţa basin).

On the field, over the deposits of Plopu Unit there was mapped a level of banks of Lucăceşti type sandstones, similar to that separated by Ionesi (1971) to the south, that we attached to the Lupoaia Unit. The unit crops out on Suceava valley and in the western part of the Cârmaci summit. In the Suceava valley crops out over the lutito-siltitic deposits of the Plopu Unit only its lower part, on 20-30 m. The upper part of the deposits is covered by Quaternary deposits. The assessed stratigraphic thickness of the unit is of 35-40 m. In this point are opened whitish or yellowish Kliwa-like quartz sandstones, which in certain sequences are brownish and pass into weakly calcareous varieties. These sandstones are massive, disposed in 1-2 m banks or beds of 40-80 cm. In the outcrop are not present silto-lutitic intercalations.

On the Tarcău nappe sedimentation area, the Lucăceşti sandstone and *Globigerina* marls Unit as well as the Lupoaia Unit are the last deposits, which end the sedimentation succession at the Eocene level.

Oligocene

During this stratigraphic period, in the Suceava – Putna – Brodina region the lithologic succession of the Tarcău Nappe begins with the Lower menilites Unit, conformably overlain by the Bituminous marls Unit, the Lower disodiles Unit and at the upper part of the column, by the Kliwa sandstone Unit.

The Oligocene deposits from this area are divided in two lithofacies: from the front of the Tarcău Nappe and up to the Falcău – Ştef tectonic line the units are developed in the Kliwa lithofacies and west of this line, in the Moldoviţa facies. As generally remarked in the external flysch, the Oligocene lithofacies are not the ones inherited from the Eocene, aspect that emphasizes once more the evolutive differences of the territory during the two stratigraphic intervals, Eocene and Oligocene. Significant differences between the deposits belonging to the two lithofacies may be seen in the western area, at the level of the Kliwa sandstone Unit, where the Kliwa sandstones are overlain by a level of curbicortical micaceous sandstones.

Lower menilites Unit. The unit has been surveyed by us on Răstoaca Mare brook, Suceava valley, Ciolotei, Glodu and Putna rivers. It was also intercepted by a series of mining works and underground drilling conducted in the area by S.C. „Geomold" S. A. from Câmpulung Moldovenesc (previous I.P.E.G. „Suceava").

In the profiles mapped on the Răstoaca brook and on Putna valley, the two members of the Lower menilites Unit were separated: the *Lingureşti marls and the Ferăstrău sandstones Member* and the *Ccompact menilites Member*.

The *Lingureşti marls and the Ferăstrău sandstones Member* presents important lithological variations both in thickness and in direction. The thickness of the sub-unit varies from 20 m to the south on Putna valley, up to 40 m to the north on Răstoaca Mare brook.

On Răstoaca Mare brook, the compact menilites are underlain by brownish marls, grey clayey limestones, brownish at the surface, with an aspect of sideritic limestones and gray-blackish clays representing almost 60-70% of the column thickness. Between these are intercalated thin beds (5-15 cm) of Kliwa-like sandstones, gray-blackish or blackish calcareous sandstones and menilites. In polarized light, in the brownish marls may be observed an isotropic mass consisting of calcite and clay minerals in which siltic allogenous quartz is disseminated.

On Putna river, under the compact menilites is developed a level of Ferăstrău quartz sandstones 20-30 m thick. The sandstones have a Kliwa-like aspect, being easily mistakable for the Lucăceşti or Kliwa sandstones. They are massive, tough and disposed in banks up to 3-6 m thick and 60-80 cm beds. From a mineralogical viewpoint, the sandstones are oligomictic, with siliceous cement replaced sometimes by a calcareous one. The lower part of the member is not visible on Putna valley.

The *Compact menilites Member* is opened out between the Lingureşti marls and Ferestrău sandstone in bed and the unit of the bituminous marls in roof. It crops out on Răstoaca brook, on the left slope of Suceava river, Ciolotei and Putna valleys, having a 10-20 m thickness. Lithologicaly it consists of an alternation of 5-15 cm menilite beds, without silto-lutitic intercalations of disodiles or brown bituminous marls. These are tough, breakable rocks, of a black, gray, brownish or banded color.

The ***Bituminous marls Unit*** is one of the recognized cartographic check points, and besides the known features, in the region they are characterized by the presence of some intercalations of quartz sandstones indicating an input of quartz arenitic material, distributed in episodes during the sedimentation. There also occur thin intercalations of disodilic argillites, in which sometimes also occur thin menilite beds.

The ***Lower disodiles Unit*** displays a series of variations both from east to west and from north to south, within the two lithofacies of Kliwa and Moldoviţa.

Another particularity characteristic for both the Tarcău Nappe and the Vrancea Nappe, is the occurrence of the Jaslo limestone, that proves the synchronism of the lower disodiles, as well as that of the lower units (lower menilites and bituminous marls), not taking in account the diminution of the bituminous character of the pelites as well as of the nature of the arenitic material (Ionesi 1986).

The ***Kliwa sandstone Unit***. On the Tarcău Nappe area from the Suceava – Putna - Brodina region (the Kliwa and Moldoviţa lithofacies), the Kliwa sandstone Unit ends the sedimentation of the flysch deposits, whereas on the area of the Vrancea Nappe from the Gura-Putnei semi-window the sedimentation basin remained functional up to the Lower Miocene.

The Kliwa sandstone Unit crops out on Răstoaca Mare brook, on the right slope of Suceava valley, Ciolotei and Măgura brooks, on the right slope of Glodu brook and on Putna valley, Suceava valley and Cârmaci summit. The thickness of the deposits varies between 60 and 110 m.

The passage from the lower disodiles is sudden, through massive banks and beds of Kliwa sandstone, in which the disodilic intercalations remain totally subordinated. Kliwa type sandstones are siliceous, coarse-grained or fine, sometimes with banded aspect, compact or friable. The thickness of the sandstone beds varies from 5-10 cm to 60-80 cm, and the banks may reach 3-5 m. The intercalations are represented by various types of bituminous rocks (disodiles) and menilites, with variable thickness from 3-5 cm up to 10-30 cm. In the typical Kliwa sandstones are also intercalated levels of blackish quartz sandstones disposed in thin beds of 5-30 cm (Răstoaca brook).

The differences between the eastern and western areas stand in the presence of curbicortical micaceous sandstone levels that occur in the Moldoviţa lithofacies, overlying the Kliwa sandstone.

The petrographic study (Ionesi *et al*., 1988) revealed the dominance of allogene minerals – 99.5 % (quartz, feldspars and heavy minerals) over the autigen ones and also the nature of the pore cement that is made of chalcedony and opal. Regarding the genesis, the authors believe that the sedimentation took place in a deep marine basin covered by a well oxygenized water sheet. As for the terrigenous source of the quartz arenitic material, the distribution of the Kliwa sandstone in the Tarcău and Vrancea Nappes denotes that this sandstone was located approximately at the limit between the two nappes (Ionesi 1979).

Grasu *et al*. (1988) showed the phases of continuous passage in the cement of the Kliwa sandstone from opal to chalcedony and then to quartz, confirming in this way the interpretation given by Filipescu (1936), according to which the sandstone's cement comes from siliceous organisms similar to those that have provided the material for the other siliceous rocks belonging to the Oligocene series.

Vrancea Nappe

The deposits of the Vrancea Nappe crop out in the eastern part of the Suceava – Putna – Brodina area, in the Gura-Putnei semi-window.

We owe the delimitation of the Gura Putnei semi-window (= Suceava semi-window; Băncilă, 1958) and the first lithostratigraphic and structural model of the Suceava – Putna – Brodina area, as a part of the overall architecture of the external flysch, to Joja (1953, 1954, 1955, 1957, 1960, 1965), Joja *et al*. (1963, 1966, 1968, 1984), Joja and Manoliu (1978). The lithostructural image presented in the above mentioned papers has not been esentially argued up to the present. The later additions made to the geologic model by Filimon and Albu (1956), Micu and Constantin (1993) and Florea (1999) just completed the geologic image already sketched by Joja.

The deposits belonging to the Vrancea Nappe were traced from Gura-Putnei semi-window to the west of the confluence of Suceava and Putna rivers, on the Gura-Putnei (and its effluent Bostan), Huta, Ţuranu and Glodu brooks (left tributaries to Putna), Ioneaca, Andronic, Scorbura Mică, Scorbura and Nistor brooks (right tributaries to Suceava) and on the left side of Suceava on Sărăturii brook (right tributary to Ziminel), in Poiana Satului (under Lomului Peak and up to the border) and on Ziminel (left effluent to Suceava). The relations between the Tarcău and Vrancea units in Glodu basin were also observed.

The visible lithostratigraphic column of Vrancea Nappe has at the base the Eocene deposits of the Sucevița Unit and ends with those belonging to the Arșița Unit, of Upper Oligocene – Lower Miocene age. The lithologic differences are not very obvious at the Eocene level, whereas in the Oligocene-Miocene column, over the Kliwa sandstone Unit are conformably disposed the deposits of the Upper disodiles and menilites Unit, and in the western part, in the front and beneath the thrust plane of the Tarcău Nappe occur Upper Oligocene – Lower Miocene deposits, considered to be an arenito-ruditic facies belonging to Vrancea Nappe, but of a western type.

As compared to Joja who considered, probably on the basis of the absence at the surface of the lower part of the Senonian-Eocene column, that in the Gura-Putnei semi-window the Eocene is developed in a particular facies, named by him the „Gura-Putnei facies" and the Oligocene is similar to that from the „Putna Nappe" (= Tarcău Nappe), our field and biostratigraphic data show on the contrary that the opened Eocene deposits embrace the lithofacial characteristics of the Doamna Eocene, specific to the eastern part of the Tarcău Nappe and that during Oligocene important lithofacial differentiations occured, related both to the area of the Tarcău Nappe and to the southern Sucevița and Humor semi-windows. Thus in

the eastern structures (Poieni anticline, Ţuranu syncline), at the level of the lower disodiles and Kliwa sandstone, the conglomerates with green rock elements are missing and the green rock fragments, with a quite low frequency, are present only in the upper disodiles from Bostan brook. In the western structures (Arşiţa rasp wedge), the conglomerates are well developed during the Upper Oligocene – Lower Miocene.

In these conditions we believe that the Eocene deposits from the Gura-Putnei semi-window are developed in the Doamna lithofacies and the Oligocene ones in a particular facies for which we used the denomination of *Gura-Putnei conglomerate facies*.

Eocene

According to the field survey we have separated at the level of the Eocene the Sucevița, Doamna - Vițeu and Bisericani Units, their deposits embracing the character of the Doamna lithofacies (= Gura-Putnei lithofacies; Joja, 1954). In the Gura-Putnei semi-window we have not identified the Lucăcești sandstone, probably due to the tectonic context.

The ***Sucevița Unit*** was identified on the right side of Suceava river (Vărăria Hill, under the Doamna limestone) and on Gura Putnei brook, where it tectonically occurs along the Vărăria fault. It represents the oldest deposits outcropping in the semi-window, as the lower part of the succession has not been intercepted at the surface. In the roof it is conformably overlain by the deposits of the Doamna – Viţeu Unit. The upper part of the unit and the contact with the Doamna limestone may be very well observed in Suceava Valley in Vărăria Hill.

In Vărăria Hill may be surveyed the upper part of the unit, opened on almost 80 m under the Doamna limestone. Towards east, the median and lower parts of the unit are covered by Quaternary deposits. At the lower part, the unit is tectonically limited, contacting Oligocene deposits.

Lithologically the unit is represented by a packet of greenish hard silto-lutitic rocks represented by silicolitic clays, silicolitic limestones and greenish fine-grained calcareous sandstones, passing into arenitic limestones; these rocks are set into 10-15 cm beds. The stratigraphic thickness of the outcrop is of almost 50 m. The arenitic sequences are usually found at the base of the silto-lutitic sequences.

Doamna – Viţeu Unit is present in complete lithologic succession on Suceava Valley, where we have separated in the lithologic column two terms with member rank: the *Doamna limestone Member* and the *Viţeu sandstone Member*. The upper member has been separated by Joja (1963) in Putna basin, under the name of „*Viţeu beds*" and by Ionesi (1971) in Humor basin under the name of „*glauconitic sandstones*". In Suceava Valley the unit has a stratigraphic thickness of 70 m.

The *Doamna limestone Member* follows over the Sucevița Unit and supports in its roof the Viţeu sandstone Member. It crops out on Suceava Valley in Vărăria Hill (near the railway) and on Gura Putnei brook. The stratigraphic thickness of the member is 55 m.

Lithologically, 80% of the column consists of limestone varieties (biomicrites and silicolitic biomicrites), interrupted at the median part by an intercalation of whitish or yellowish coarse-grained sandstones with microconglomeratic aspect, with green rock elements. From this level Joja and Manoliu (1978) have evidenced the *Nummulites* fauna from "La Vărărie".

The limestones have different colors, from white-yellowish to brown, greenish or grayish and banded. As did Joja (1954) and Micu and Constantin (1993), in these rocks we also observed the low frequency of the *chaille* type silicifications. As for the arenitic material intercalations, we showed them to be present also in the Doamna limestone Member from the Scorbura – Doamna lithofacies, in the section from Calanceni brook, and therefore, this criterion cannot be used as a differentiation element of the Doamna limestone between the two

units, as Micu and Constantin (1993) have affirmed. Also the silto-lutitic intercalations (green-grayish clays and marls) are reduced in the column of this member, both as thickness (3-10 cm) and as frequency.

The *Viţeu sandstone Member* conformably overlies the Doamna limestones and supports the red and green Strujinoasa clays that crop out at west, on Ioneaca brook and at the confluence of Bostan with Gura Putnei brooks.

It consists of an alternation of gray-greenish marls and clays, in which are intercalated 10-25 cm beds of greenish glauconitic calcareous sandstones, with graded sorting and bottom hieroglyphs. They are microconglomeratic or coarse-grained in the basal sequences, and present many lithological similarities with the Viţeu sandstone Member described in the Scorbura – Doamna lithofacies. The thickness of the member in Vărăria Hill is of 20 m.

Plopu-Bisericani Unit. The field data allowed the separation in the Gura-Putnei semi-window of two lithologic terms: the *Strujinoasa red clays Member* and the *Green and grey clays Member*.

The *Strujinoasa red clays Member* is opened on Ioneaca and Gura-Putnei brooks and at the confluence of Bostan with Gura Putnei. It is 20 m thick and is made of an alternation of red-tiled, green or banded clays, with grey or greenish-grey glauconitic quartz sandstones disposed in 5-15 cm beds, with bottom hieroglyphs.

The *Green and grey clays Member* is opened on Ioneaca, Gura Putnei and Bostan brooks. Its stratigraphic thickness reaches 300 m on Bostan brook and the upper limit is tectonised. Lithologically, it consists of grey-greenish calcareous clays and clays with intercalations of green quartz sandstones, blackish calcareous sandstones and lithic sandstones in thin beds, with bottom hieroglyphs. The arenitic sequences from the silto-lutitic deposits are quantitatively subordinate.

At the upper part of the green and grey sandstones we could not identify the Lucăceşti sandstones and we were not able to separate the *Globigerina* marls – fact that is consistent with Joja's affirmation (1954) regarding the absence of the Lucăceşti sandstone in the „Gura-Putnei facies". We believe that the absence of the Lucăceşti sandstones and the *Globigerina* marls is the consequence of the semi-window tectonics and not of the sedimentation conditions. On the geologic map (appendix 3, 4) may be observed that invariably the upper part of the Bisericani unit is tectonically limited.

Oligocene – Lower Miocene

The data we have obtained from the field surveys performed west of the confluence of Suceava and Putna, corroborated with the information from S.C. „Geomold" S.A. research and with the information provided by hydrocarbon drilling in Suceava and Putna valleys, allowed the separation within the Oligocene – Lower Miocene succession of the Lower menilites Unit, Bituminous marls Unit, Lower disodiles Unit, Kliwa sandstones Unit, Upper disodiles and menilites Unit and Arşiţa Unit.

The ***Lower menilites Unit*** has been mapped on the left slope of Suceava valley, in Afinet Hill and on Suceava's right slope on Scorbura and Scorbura Mică brooks. The lithologic context allowed the separation of the two members of the unit: the *Lingureşti marls and Ferăstrău sandstones Member* and the *Compact menilites Member*.

The ***Bituminous marls Unit*** has been traced on the right bank of Suceava river (in the Ţuranu Hill outcrop), on the right tributaries of Suceava (Scorbura, Scorbura Mică and Andronic) and on the left bank of Suceava (in Afinet Hill). The relations with the lower and upper units are clearer in the area of the Scorbura - Scorbura Mică - Andronic brooks and in Afinet Hill. In Ţuranu Hill (in the railway area), although the deposits are opened on 100 m and a very good description of the petrographic variety of the unit may be done, the contacts with the bed and roof deposits are not visible. The bituminous marls are very well developed

both in the Poieni anticline (the right and left banks of Suceava) and in the Ţuranu syncline (right slope of Suceava, railway area), reaching thicknesses of 70 m.

Lithologically, the bituminous marls generally present stratification (5-25 cm beds), are tough, compact, with thin disodilic or menilitic intercalations. They have a whitish color on surface due to the organic oxidation and they generally present brownish, grayish or banded colors in fresh breach. The disodiles and menilites are developed as centimetric beds or as lens-shaped bodies. The percentage of these intercalations does not exceed 5% of the column.

In the median part occur a few 10-15 cm thick beds of grey, grey-greenish or yellowish sideritic limestones, that if were not to be intercalated in the typical bituminous marls would have been easily mistaken for the Doamna limestone. Both in the mass of this limestone and in the bituminous marls are present menilitic silicifications of the *chaille* type. We believe that the sequential survey of some profiles where the limestones belonging to the Bituminous marls Unit could have been interpreted as Doamna limestones, have led to the sketching of some syncline or reversed anticline structures drawn by Micu and Constantin (1993) on the map that accompanies the text.

The unit mapped by us is litostratigraphically close to the similar units described in the Putna – Sucevița area by Florea (1999) and in Soloneț – Sucevița – Moldovița area by Bogatu (1999), in a higher proportion than that described by Micu and Constantin (1993) in the Gura-Putnei semi-window.

The ***Lower disodiles Unit*** crops out on Suceava's left bank, in Afinet Hill and on its right bank on the Scorbura, Scorbura Mică and Andronic brooks. The unit's thickness varies from 50 m in Afinet Hill to 85 m on Suceava's right bank.

As already known, the disodiles occur as clayey rocks, rarely clayey-marly, bituminous, in which are also intercalated rocks with low or even without bituminous content. The disodiles have a brownish or blackish color, a pronounced lamination and present on the beds surfaces sulphur, gypsum and limonite efflorescences representing secondary weathering products of pyrite. The arenitic intercalations that do not exceed 30 % of the rock mass are represented by yellowish quartz sandstones of Kliwa type, usually disposed in thin beds. Sometimes these sandstones have suffered a bituminization process and have a blackish color, or pass into rocks consisting of alternations of lutitic and arenitic material.

In Afinet Hill, in the disodiles, a conformable 15 m thick bed of bituminous marls occurs, that we interpreted as being olistolithic. This affirmation is based on the fact that such olistolithic bodies occuring in the lower disodiles mass have been emphasized in Humor and Tarcău Units by Ionesi and Grasu (1993). Commenting the relations of the olistolithes with the host rocks, these authors show that in the case of lens-shaped bodies longer than their thickness, they are concordant with the stratification and the direction of the disodiles, fact that is also valid in our case. In the same outcrop we have identified the Jaslo limestone, in 3-5 cm thick beds, banded or gray-whitish, with *chailles*, summing up to 2 m.

Kliwa sandstone Unit. Referring to the Kliwa sandstones Unit, Micu and Constantin (1993) indicate that it occurs on a quite limited area, representing the filling material of a syncline situated between Gura-Putnei and Suceava River, which continues in the left slope in Deluţul Hill. West of this syncline these deposits are very rare: they appear only on a limited area west of Ziminel Gulf and along some tributaries of Suceava, south of Straja. As a characteristic feature of the unit, in Gura-Putnei semi-window is emphasized the absence of green rocks along the entire studied section.

The situation we mapped in the field is somehow different from that presented and figured on the map accompanying the paper by Micu and Constantin (1993). The field data allowed the separation of this unit into two important structures of the semi-window: to west, on the northeastern (Afinet Hill) and southeastern (Scorbura Mică and Andronic brooks) flanks of the Poieni anticline and to east, as the filling material of the Ţuranu faulted syncline

(Gura Putnei brook). Its thickness varies from 80 m in Afinet Hill to 125 m in the right slope of Suceava (Scorbura and Andronic brooks).

Lithologically, some differences may be observed between the outcrops situated north and south of Suceava valley, on one hand, and between the eastern and western ones, on the other. In Afinet Hill the unit is represented by Kliwa sandstones beds up to 60 cm thick, between which are intercalated disodiles and thin beds of blackish quartz sandstones, up to 30-40 cm thick. The disodilic intercalations represent up to 40% of the column. South of Suceava valley, in the sections from Andronic and Scorbura brooks, the lithologic aspect changes, the Kliwa sandstones becoming massive, disposed in 30-80 cm beds or banks of 1-2 m thick, in which the disodilic intercalations are lesser than 20%. The typical Kliwa sandstones pass in the median part into a 10-15 m thick packet of 10-20 cm beds of blackish tough quartz sandstones. On Gura Putnei brook the unit is formed of an alternation of Kliwa sandstone beds of maximum 15 cm thick, where in the lower part disodiles up to 10 cm thick are intercalated.

According to Micu and Constantin (1993) observations, the conclusion that within the Kliwa sandstones Unit from the Gura-Putnei semi-window, the green rock element conglomeratic intercalations are missing, remains valid. In our opinion, the conglomerate fragments and the green rock element conglomerates, more abundant in the western part of the semi-window, come from the arenitic conglomerate deposits of Upper Oligocene – Lower Miocene age, that corresponding to a more western facies of the Vrancea Nappe, separated by us as the Arşiţa Unit. Also, the massive gray weakly calcareous sandstones, that are found on the right slope of Suceava (railway area), under the thrust plane of Tarcău Nappe, interpreted as being Kliwa sandstones by the above mentioned authors, were attached by us on lito- and biostratigraphic grounds to the Arşiţa Unit.

The ***Upper disodiles and menilites Unit*** outcrops in the northeastern slope of Scorbura Hill, the upper disodiles being conformably disposed over the deposits belonging to the Kliwa sandstone Unit. The establishment of the disodiles real position is possible only by surveying the profiles opened in Suceava's right bank, on Scorbura Mică brook (confluence with Suceava) –Scorbura Mică brook – springs of Bostan brook and Bostan (up to the confluence with Gura Putnei) and on Suceava's left bank in Afinet Hill– springs of Sărăturii brook – Lomul Peak. The unit crops out only on the flanks of Poieni anticline.

Lithologically, the upper disodiles are generally similar to the lower ones, consisting of typical bituminous rocks alternating with different sandy varieties and intercalations of Kliwa sandstones, blackish quartz sandstones and thin menilitic strata. The sandstones beds sometimes present lens-shaping, probably synchronous with the folding processes. Also, in some bituminous sequences rounded fragments of green rocks occur. In the disodiles is intercalated a 10 m thick level of bituminous marls, which we have interpreted as an olistolithic body (visible at almost 100 m north of the intersection of Bostan brook with the Straja – Putna forestry road).

The unit described by us presents lithological differences from that in Sucevița semi-window, where on Șoarecu brook the conglomerates with green rocks elements of different size invade the Upper disodiles Unit up to its total replacement. The substitution takes pace gradually from disodiles with rare elements, to weakly consolidated rudites with clayey-disodilic matrix (Florea, 1999).

Micu and Constantin (1993) attached the bituminous rocks with intercalations of blackish quartz sandstones and green rock elements to the Conglomeratic Unit, that would find itself in transgressive relationship with the Eocene-Oligocene deposits.

Arşiţa rasp wedge

The deposits belonging to this unit crop out only in Suceava valley and are of Upper Oligocene-Lower Miocene.

Upper Oligocene – Lower Miocene

Arşiţa Unit. The deposits of this unit have been surveyed on Suceava's left slope, in the Afinet Hill – Sărăturii brook and on the right bank, in the sector Straja railway station – Nistor brook – springs of Scorbura brook. Both the lower and the upper part of the lithologic column are tectonically limited, by Arşita fault and by Tarcău Nappe thrust plane, respectively. The specific note of the unit is given by the arenito-conglomeratic aspect of the deposits and the presence of green rocks elements conglomerates in the lower and upper part of the unit.

Analyzing the lithostratigraphic variations of the unit's column, we were able to separate three lithologic sub-units of member rank: *Sărătura Member*, *Suceava Member and Nistor Member*.

Sărătura Member has been separated on Suceava's left bank, at the springs of Sărăturii brook. Here, beyond the upper disodiles outcrop, the terrain is covered on almost 70-100 m and then it is opened on 80 m, revealing a conglomeratic succession in base and sandstones at the upper part.

The 40 m thick conglomeratic deposits are represented by conglomerates and micro-conglomerates with green rocks elements, fixed in a grey or greenish silto-lutitic matrix.

The green rocks fragments are dominantly sub-centimetric, rarely sub-decimetric and highly worked. In the same deposit are subordinately intercalated blackish micaceous sandstones, in 5-10 cm thick beds and silto-lutitic sequences of grey, greenish or grey-greenish color, 10-30 cm thick. The conglomerates and micro-conglomerates occupy almost 50% of the succession.

Over these deposits follow grey, yellowish or whitish weakly calcareous sandstones, without silto-lutitic intercalations, opened on a thickness of almost 50 m, which we attached to the Suceava sandstones Member.

Suceava Member outcrops both in the left (Sărăturii brook) and in the right bank of Suceava river (sector railway station –Nistor brook) and on Nistor brook. The best outcrops are those from the right bank of Suceava, where above a 2 m level of grey and greenish silto-lutites with intercalations of calcareous sandstones and whitish quartz sandstones disposed in 5-30 cm beds (at the railway station near the confluence of Nistor brook with Suceava) and attached to the Lower conglomeratic Member, conformably overlies a monotonous sandstone succession with a stratigraphic thickness of 150 m.

Nistor Member has been separated at the upper part of the unit's column, as being conformably disposed over the Suceava sandstones. At the upper part it is tectonically limited, being covered by the deposits of the Hangu Unit of the Tarcău Nappe. The stratigraphic thickness of the member was estimated at 80 m. It crops out in the spring area of Scorbura and Nistor brooks.

The column begins with an alternation of blackish micaceous coarse-grained, graded sorted sandstones, in thin beds of 3-10 cm, overlain by an alternation of grey-greenish or grey-blackish silto-lutites, with micro-conglomerates with green rocks elements, with a grey-greenish matrix, and 1-3 cm thick beds of grey limestones. This 22 m thick level is overlain by green or green-blackish marls with rare and thin intercalations of blackish micaceous sandstones (1-3 cm). Towards the upper part of the outcrop there is an interesting 3 m thick level of whitish marls fragments, of medium plasticity, fixed in plastic marls and grey-greenish clays.

The upper part of this section is covered by deluvial deposits and is opened under Scorbura summit, in the area of the erosion limit of the Tarcău Nappe thrust over the Vrancea Nappe.

BIOSTRATIGRAPHIC CONCLUSIONS

Biostratigraphically, the units from Suceava – Putna – Sucevița area have been characterized on the basis of the calcareous nannoplankton associations determined by us as well as of the literature information regarding the fauna of agglutinate micro-foraminiferans, macro-foraminiferans and bivalves from the deposits of the external flysch.

The biostratigraphic observations included in the present paper refer to two aspects:

- the unit assignment in corresponding stratigraphic intervals, on the basis of the nannoplankton associations determined and of the existing data;

- the discussion of the Senonian – Paleocene, Eocene – Oligocene and Oligocene – Lower Miocene limits, mainly on bibliography basis.

Hangu Unit is characterized by a wealthy and diversified but not always relevant paleontological inventory, leading over time to the assignment to different ages.

From the Senonian deposits succession and more precisely from the Sandy-marly-clayey Member and from the Upper *Chondrites* marls Member, four samples were collected (16np, 17np, 34np and 38np). From the analyzed thin slides, two nannoplankton associations were discovered, characteristic for the Upper Santonian – Campanian (biozones CC_{16}-CC_{23}) and Upper Maastrichtian (CC_{25}).

Izvor Unit is characterized through a diversity of organism groups that have quite homogeneous biostratigraphic significations.

Large foraminiferans (Ionesi 1971) indicate for this unit the Paleocene age. Micro-foraminiferans, represented through rich and diverse faunas, indicate different, but quite grouped ages: Danian-Paleocene (Joja *et al*. 1963), Danian (Ionesi; Tocorjescu, 1968 - for the basal part of the unit), Danian-Paleocene (Dicea 1974), Danian-Upper Paleocene (Alexandrescu and Bratu 1975).

The micro-flora studied by Olaru (1974, 1978) indicates for the Izvor Unit the Paleocene age. The calcareous nannoplankton analyzed by Ionesi and Mészáros (1995) in the upper part of the unit brings arguments for ascribing the deposits to Biozone NP_{11} of Lower Eocene age.

From the Izvor Unit deposits, six samples were collected (1np, 10np, 11np, 15np, 24np, 41np and 42np) from the lower, median and upper part of the lithologic column, in order to perform nannoplankton analysis. The biostratigraphic signification of the determined fauna enables us to consider that the Izvor Unit spans over the Paleocene (biozones NP_5-NP_9) – Lower Eocene (NP_{10}-NP_{11}) stratigraphic interval.

Surcele Unit. The stratigraphic position of the unit was established on the basis of the geometric relations of continuity with the deposits of the Izvor Unit from the bed and those of the Straja Unit from the roof, as well as of the biostratigraphic significations offered by the nannoplankton associations identified from the clayey levels situated immediately under or above the Scorbura level.

As seen from the age discussion of the above and below units, Surcele Unit obviously belongs to the upper part of the Lower Ypresian and to the base of the median Ypresian (it is intercalated between biozones NP_{10}-NP_{11}, characteristic to the Lower Ypresian and biozone NP_{12}, medium Ypresian).

Straja Unit. The age of this unit was ascribed to the Paleocene – Lower Eocene interval, on the basis of the foraminiferan faunas.

The large foraminiferans have been used as indirect arguments by Ionesi (1971), who ascribes to the mentioned deposits an Upper Paleocene (Ilerdian) age.

According to other authors, the micro-foraminiferans certify other ages: Paleocene (Joja *et al*. 1963) and Lower Eocene (Ypresian) (Costea *et al.*, 1962; Agheorghiesi *et al.*, 1966; Alexandrescu *et al.*, 1970; Dicea, 1974).

The micro-flora analyzed by Olaru (1978) characterizes through its palinologic content a period of passage from Paleocene to Lower Eocene.

From Straja Unit, from the sections opened on Boului and Străjii brooks and Caraula sector, nine samples were collected (2np, 3np, 4np, 5np, 6np, 7np, 8np, 9np and 14np) for nannoplankton analysis. On the basis of the identified faunas we consider that the age of Straja Unit is medium Ypresian, corresponding to biozones NP_{12} and NP_{13}.

Scorbura Unit. From a biostratigraphic viewpoint the deposits synchronous to the Scorbura Unit have been studied by Ştefănescu (1927), Joja *et al.* (1963), Bombiţă (1973), Dicea (1974), Ionesi (1967, 1971, 1997, 1999), Florea (1999). The emphasized biostratigraphic aspects are presented in the section on the Suceviţa and Scorbura – Tazlău Units.

For the biostratigraphic assignment of the deposits belonging to the Scorbura Unit, four nannoplankton samples were collected from the pelitic sequences of the profile opened on Suceava valley, Caraula sector. Two samples were collected from the bed (19np) and roof (13np) deposits and two from the pelites intercalated in the quartz sandstones banks of the Scorbura Unit (21np and 35np). From Glodu brook only one sample has been collected (39np) from the base of the Calanceni Member.

From the nannoplankton association analysis, Scorbura Unit belongs to the Upper Ypresian – Lutetian (NP_{13}-NP_{15}) range. At the same time, it is worth to be mentioned that the upper Scorbura sandstones that overlie the silicolitic level and come into direct contact with the Doamna limestone, could represent the equivalent of the *Asterocycline* sandstones separated to the south of Putna river, in Moldoviţa basin by Ionesi (1961, 1971) and in Suceviţa basin by Florea (1999).

Doamna – Viţeu Unit. From the deposits of this unit, two samples were collected (13np and 12np) from the section cropping out on Calanceni brook (right tributary to Suceava), for calcareous nannoplankton analysis. Under the microscope was evidenced a fauna whose bio-stratigraphic signification allows us to integrate the Doamna limestone Unit to the Bartonian (NP_{17}) stratigraphic interval.

The age attributed by us is consistent with the stratigraphic significance of the large foraminifers discovered in this unit by Ionesi (1971) and Joja and Manoliu (1978), which indicates the fact that the above mentioned deposits are of Bartonian age. *The* micro-flora evidenced by Olaru (1978) is considered as being of Biarritzian age.

Scorbura – Tazlău Unit. From the turbiditic sequences of the upper part of the column, two nannoplankton samples have been collected (22np and 23np), of which we evidenced a fauna specific for the Bartonian (NP_{17}).

Plopu-Bisericani Unit and ***Plopu Unit*** have been considered of Priabonian age on the basis of the nannoplankton identified in the samples collected from the section from Măgura brook, Suceava valley and Bodnar brook (NP_{18}-NP_{19}).

The ***Lucăceşti sandstone and Globigerina marls Unit*** has been the object of laborious biostratigraphic research. The large foraminiferans signaled by Băncilă (1955, 1958) and determined in the Ardeluţa Unit by Ionesi (1957, 1971), are characteristic for the Upper Eocene (Priabonian).

The planktonic micro-foraminiferans characteristic to this member (*Globigerina*) emphasized by all the scientists that studied this area reveal an Upper Eocene age. The micro-flora analysis conducted by Olaru (1978) confirmed the presence of some forms signifying from a chronologic viewpoint a transition from Upper Eocene to Oligocene.

The study of calcareous nannoplankton associations has resulted in quite interesting and contradictorily interpreted results: Martini and Lebenson (1971), Lebenson (1973), Dicea and Dicea (1976) consider that the unit belongs to biozone NP21, of Oligocene age, whereas Ionesi and Mészáros (1989), Ionesi *et al.* (1995) consider that it belongs to biozones Np_{20} (terminal part) and NP_{21}, of Upper Eocene age. Dicea and Dicea (1980), Ionesi and Florea (1981) and Florea (1982) consider the same deposits as belonging to biozones NP_{19} –NP_{20} and

NP_{20}, respectively, of Upper Eocene age, while Micu and Gheţa (1986) assigned them to biozone NP_{22}, the attributed age being Oligocene.

We have collected and analyzed 4 nannoplankton samples from the Lucăceşti sandstones and *Globigerina* marls Unit, from Răstoaca brook. The determined fauna is Upper Priabonian, corresponding to biozones NP_{20}-NP_{21}.

Arşiţa Unit. From the silto-lutitic intercalations of the Arşiţa Unit, four samples for the nannoplankton analysis were collected from the profile cropping out in Suceava's right slope, from the confluence of Nistor brook with Suceava, up to the springing area of Scorbura brook.

From the investigated samples we have evidenced a rich calcareous nannoplankton association, consisting of 27 taxons. In this fauna, along the taxons with a large stratigraphic distribution and with no specific importance for age research, is remarked the presence of some species with a relevant biostratigraphic significance for deposit dating.

According to the standard biozoning, the deposits from which the samples where collected may be classified regarding the calcareous nannoplankton content into biozones NP_{25}, NN_1 and possibly the base of biozone NN_2, ascribing the deposits an Upper Oligocene – base of the Lower Miocene age.

In order to biostratigraphically correlate the deposits of the Arşiţa Unit, an appeal to a series of studies must be done, in which the age of the Gura Şoimului and Vineţişu Units was analysed. The age of Gura Şoimului Unit has been established on the basis of plankton foraminiferans and of calcareous nannoplankton, in the studies conducted by Ionesi and Gheţa (1978), Dicea and Dicea (1980), Micu *et al*. (1984), Ionesi and Bogatu (1986), Ionesi and Mészáros (1990), Brustur and Alexandrescu (1990), Ionesi (1991).

Ionesi and Gheţa (1978) and Ionesi and Bogatu (1986) emphasized a fauna of autochthonous micro-foraminiferans with *Globigerinoides primordius*, *G. trilobus*, *G. immaturus*, *G. sicanus*, that indicates a Lower Burdigalian age, and Ionesi and Gheţa (1978) determined for the first time from the deposits from the base of Gura Şoimului Unit (Humor Unit) a nannoplankton association with *Sphenolithus belemnos*, *Helicosphaera kamptneri*, *H. ampliapertura*, *Reticulofenestra lockeri*, that belong to the terminal part of biozone NN_3 and the base of biozone NN_4.

Dicea and Dicea (1980) emphasized from the deposits of Gura Şoimului in the Bistriţa and Slănic-Oituz semi-windows the taxons *Helicosphaera kamptneri*, *H. ampliapertura*, *Sphenolithus belemnos* and *Discoaster druggi*, characteristic for biozone NN_2.

Micu *et al*. (1984) consider that the largest part of nannoplankton from the Gura Şoimului Unit is reworked, as allochtonous fauna is identified only from the upper part, with *Helicosphaera carteri*, *H. ampliapertura*, *H. transylvanica*, *Reticulofenestra pseudoumbilica*, which are assigned to biozone NN_3.

Ionesi and Mészáros (1990) determined in Humor semi-window from the Gura Şoimului Unit, from beneath the „Slatina tufa", a nannoplankton association characteristic to biozone NN_2 (with *Helicosphaera kamptneri* and *H. carteri*) and from the deposits overlying the tufa level a fauna considered to belong to biozones NN_2 and the base of NN_3 (with *Discoaster druggi*, *Helicosphaera kamptneri*, *H. ampliapertura*).

On the basis of the existing data, Ionesi (1991) correlated the Miocene deposits from the Tarcău and Vrancea Units, concluding:

- the Gura Şoimului Unit is newer than that of Vineţişu, being equivalent with Cornu Unit;

- the Gura Şoimului Unit from the Slănic-Oituz semi-window is equivalent with that of the peri-Carpathian molasse, which is consistent with the data presented above;

- Podu Morii and Vineţişu Units are not synchronous, according to the data offered by the fossil plant record from the Jaslo limestone from Buzău and Teleajen valleys (Brustur and Alexandrescu, 1990).

Considering the previous discussion, and the data that we have at the moment we can correlate the deposits belonging to the Arşiţa Unit with those of the Vineţişu Unit and possibly with the upper part of the Upper disodiles Unit.

CONCLUSIONS REGARDING THE AREA TECTONICS

In the Suceava – Putna – Brodina area crop out deposits that belong to two major tectonic units, with nappe rank: in the eastern part, in Gura–Putnei semi-window, the Vrancea Nappe (sens Ionesi, 1968; = the marginal folds nappe, Săndulescu, 1984) and to the west, the Tarcău Nappe. From the genesis viewpoint and their position within the flysch basin, the Tarcău and Vrancea nappes are situated in the domain of the external flysch (Ionesi, 1968), and on tectogenetic criteria, they are assigned to the Moldavides (Săndulescu, 1984), as their structure and major thrusting were realized during the Miocene tectonic phases.

The separation of the two units in Suceava valley and the drawing of the erosion limit of Gura-Putnei semi-window, as it is figured on the 1:200.000 geologic map, sheet 5 Rădăuţi, are owed to Joja (1954, 1955, 1957, 1960). Referring to the thrusting of the Upper unit to the north and south of Suceava river, Joja (1955) shows that the „*Lower Senonian thrusts in the area of Slatina brook (=Sărăturii, n.n.), directly over the Upper conglomeratic Oligocene of the Lower Unit. The same Lower Senonian continues also on the right bank of Suceava, east of the Straja-Ferestrău railway station, where it oveliesr the micaceous sandstones of the Upper Oligocene ... The Senonian thrust line over the Oligocene from Slatinei brook of Straja is the extension of the thrust line from Gura Putnei semi-window".*

From our field data results that the Tarcău Nappe thrust front follows in the southern part the right bank of Gura Putnei brook, on a northeast-southwest direction, up to the springing area of Glodu brook, then it goes towards NNW, under the Scorbura and Lomul summits, crossing Suceava valley through the western part of Straja (by „the end of the village"), fact that is highly consistent with the situation presented by Joja.

Our concerns regarding the investigated area tectonics have been oriented in the following directions:

- the description of the folding and thrusting structures belonging to the two nappes;
- the correlation of the structural elements from the area with those found south of Putna river, in Sucevița and Moldovița basins;
- the presentation of the relations between the Tarcău and Vrancea nappes on one hand and of the Vrancea and Subcarpathian nappes on the other.

Tarcău Nappe

From a tectonic viewpoint, the area corresponding to the Tarcău Nappe is complicated by faulted overturned folds and rasp wedge, as on a cross-cutting line of only 12 km as much as 7 faulted overturned folds with eastern vergence and a shear thrust wedge may be observed.

In the Suceava – Putna – Brodina area, the Tarcău Nappe presents a faulted overturned folds structure, with north-northeastern vergence, separated by reversed faults along which the eastern flanks are usually laminated. The main structural elements mapped from east to west are the following:

Lomul – Scorbura faulted overturned fold. The lithologic column of this structure consists of the Hangu, Izvor, Surcele, Straja, Sucevița Units and Doamna Member, as the upper part of the column is cut off by the above mentioned faults. The Eocene deposits of this structure are developed in the Doamna lithofacies.

Straja faulted overturned fold. The deposits of this structure crop out on Suceava valley between the confluences of Suceava River with Humăria and Boului brooks and on the left bank of Boului valley, up to the confluence between Boului and Sihastru brooks. Towards east it successively covers along Boului fault the Izvor, Surcele, Straja, Sucevița Units and the

Doamna limestone Member of the Lomul – Scorbura faulted overturned fold. To the west it contacts the deposits of Hangu and Izvor Units (on Suceava valley), of the Bâtca – Glodu faulted overturned fold, along Jijia fault.

In the Suceava valley outcrop it consists exclusively of massive quartz glauconitic sandstones of Scorbura type, associated with, on Boului brook, a basal alternation of red and green clays with thin beds of fine-grained quartz glauconitic sandstones, 50-60 cm thick.

These deposits constitute the western flank of an anticline with the vertical axial plan situated in the left bank of Suceava valley; this plan suffers a distorsion towards south, in the left slope, on Boului valley, presenting declivities of $50\text{-}60^0$ SW. Because of their bulk and uniform character, the sandstones from this structure may be attached to any of the Surcele, Scorbura or even Sucevița Units, knowing that Scorbura type sandstones banks occur also in the latter at different levels. In the lithostructural context of the area, we have chosen to consider that these sandstones make up the lower part of Scorbura Unit, characteristic to the Eocene Scorbura – Doamna lithofacies, especially because on Boului brook, at the base of the sandstones a thin level of silto-lutites occurs belonging to the upper part of Straja Unit.

As for the the distorsion of the axial plan from north to south, considering the brittleness of the rocks that make up the anticline, we believe that the process was realized along a succession of transversal faults, contemporaneous with the folding and eastern displacement of the faulted overturned fold.

The assignment of the deposits belonging to this structure to the Scorbura-Doamna lithofacies shows that the deposition area of this lithofacies has been much larger in this sector and its reduction to a relatively narrow outcropping stripe is due to tectonic processes.

Bâtca – Glodu faulted overturned fold. The lithologic column of this structure includes deposits belonging to the Senonian (Hangu Unit), Paleocene (Izvor Unit), Eocene in the Scorbura – Doamna lithofacies (Surcele, Straja, Scorbura, Doamna – Vițeu, Plopu-Bisericani and Lucăcești sandstones and *Globigerina* marls Units) and Oligocene in Kliwa lithofacies (Lower menilites, Bituminous marls, Lower disodiles and Kliwa sandstone Units).

Poiana Crucii faulted overturned fold. This structure was identified only on Putna valley, between Icoana fault to the east and Falcău – Ştef fault to the west. The structure crops out towards south, as to the north of Putna valley it is entirely covered by the units belonging to the Crucii – Stauina – Sihăstria faulted overturned fold. On Putna valley it consists exclusively of Paleocene deposits of the Izvor Unit.

Crucii – Stauina – Sihăstria faulted overturned fold. The lithologic column of this structure is made of deposits belonging to the Senonian (Hangu Unit), Paleocene (Izvor Unit) and Eocene in Scorbura – Tazlău lithofacies (Straja, Scorbura – Tazlău, Plopu and Lupoaia Units).

Șandru – Măgura Vacii faulted overturned fold. This structure consists of deposits belonging to the Senonian (Hangu Unit), Paleocene (Izvor Unit), Eocene in Scorbura – Tazlău lithofacies (Straja, Surcele, Scorbura – Tazlău, Plopu and Lupoaia Units) and Oligocene in Moldoviţa lithofacies (Lower menilites and bituminous marls, Lower disodiles and Moldoviţa Units).

Solovanu faulted overturned fold. This structure extends west of Brodina fault, line that has important tectonic effects. Along this fault the deposits of the Hangu Unit cover in the Cârmaci brook basin Eocene units of the Crucii – Stauina – Sihăstria faulted overturned fold, and on Suceava valley and Brodina basin the Kliwa sandstone from Șandru – Măgura – Vacii faulted overturned fold. As our research from this stage stopped west on the Brodina – Brodinioara brooks line, we do not have supplementary arguments regarding the development of this structure towards west.

Măgura rasp wedge. It represents a part of the Crucii – Stauina – Sihăstria faulted overturned fold that covers completely on Măgura brook the Paleocene-Eocene deposits of the

Bâtca – Glodu faulted overturned fold, its front contacting the Hangu Unit. The deposits of this structure, caught between Măgura fault to east and Falcău – Ştef fault to west, have in base on a 3-5 m thickness red and green clays from Strujinoasa Member, tectonically overlain by a 1-2 m menilites bed followed by the Kliwa sandstones Unit, on a stratigraphic thickness of 80-100 m, up to the Hangu Unit from Crucii – Stauina – Sihăstria faulted overturned fold.

The successive covering along the Falcău – Ştef fault of the deposits belonging to Bâtca – Glodu and Icoana faulted overturned folds, as well as and the presence of Măgura rasp wedge from the front of Crucii – Stauina - Sihăstria faulted overturned fold draws the attention on the importance of the tectonic effects of this fault, fact already remarked by Joja (1955).

In order to correlate the structural elements identified by us in the Suceava – Putna – Brodina area we have used the literature data from Joja (1954, 1955, 1957), Ionesi (1971), Micu (1981), Ionesi and Florea (1984), Ionesi and Grasu (1986), as well as the structural model of the Tarcău and Vrancea Nappes proposed by Săndulescu (1984).

Analyzing the tectonic data presented by us and the structural context sketched for the Sucevița – Moldovița area, we may infer the following:

- Jijia reversed fault, that marks the front of the Bâtca – Glodu faulted overturned fold (= Şoloteiul fault; Joja, 1957), may be interpreted to the south in two ways: a – according to the model proposed by Micu (1981), it is continued by Dragoşina fault and in this case, Bâtca – Glodu faulted overturned fold (= Şoloteiul overflow fault fold; Joja, 1957) would be continued by Dragoşina faulted overturned fold, and the eastern Lomul – Scorbura (= Scorbura faulted overturned fold; Joja, 1957) with Sucevița faulted overturned fold; b – according to the model of Ionesi and Florea (1984) and Ionesi and Grasu (1986), Jijia fault stops south of Putna river, in the transversal fault that limits towards north Sucevița semi-window. In this situation the deposits belonging to Bâtca – Glodu and Lomul – Scorbura faulted overturned folds have been eroded after the raising movements of the southern sector;

- according to our data from Putna valley, Falcău – Ştef reversed fault (= Poiana Crucii fault; Joja, 1957) is prolonged towards south by Merța – Bobeica fault. This tectonic accident is an important one through its effects. As we may see from the mentioned data, it carries in the front of the Crucii – Stauina – Sihăstria faulted overturned fold the Măgura rasp wedge and provokes the thrust and complete covering north of Putna valley of the deposits belonging to Poiana Crucii faulted overturned fold

Crucii – Stauina – Sihăstria faulted overturned fold, delimited to the west by Ascuncelul fault (= Măgura fault; Joja, 1957) develops only to the north of Putna valley, to the south being limited by the plane of Falcău – Ştef fault. The continuation towards south of the Şandru – Măgura Vacii faulted overturned fold (= Măgura faulted overturned fold; Joja, 1957) is represented by Obcina Mare faulted overturned fold, with which begin towards west the internal skibbes (Micu, 1981).

Falcău – Ştef line has also a lithofacial significance, meaning that west of it the Eocene deposits are developed in the Scorbura – Tazlău lithofacies and the Oligocene ones in Moldovița lithofacies. These lithofacial characteristics are also maintained to the south, as Ionesi (1971) separated west of Merța – Bobeica line the Eocene in Tazlău lithofacies and the Oligocene in Moldovița lithofacies.

If we refer to the digitations separated by Săndulescu (1984) then through the dimension of the tectonic effects in the area as well as of the lithofacial significations, Falcău – Ştef line is a tectonic accident that may represent the front of the Tazlău digitations in Suceava valley (the internal skibbes, Micu, 1981);

- Brodina fault is continued to the south probably by Dobra – Lupoaia fault, separating to the east the Solovanu faulted overturned fold (= Brodina faulted overturned fold; Joja, 1957).

Arşiţa rasp wedge

Arşiţa tectonic unit is a rasp wedge carried in the front of Tarcău Nappe from a western area of the Vrancea Nappe sedimentation realm, probably during the intra-Badenian thrusting.

The deposits of this structure crop out on Suceava's left bank, on Sărăturii brook, on Nistor's brook right bank and at the springs of Scorbura brook, from beneath the Senonian deposits of the Hangu Unit from Tarcău Nappe. Towards east it thrusts along the Arşiţa reversed fault over the Eocene-Oligocene deposits of Poieni anticline. The rasp wedge consists of Oligocene-Lower Miocene calcareous sandstone deposits of the Arşiţa Unit.

This western facies made of „*... a thick series of yellowish coarse-grained, micaceous, fossilless Tarcău type sandstones, in banks of 1-2 m, with rare intercalations of similar, but conglomeratic sandstones, as well as of green elements micro-conglomerates*" from beneath the Tarcău Nappe thrust plane from Suceava valley has been discovered by Joja (1954). The author parallels them with „*Polaniça beds*", disposed in Pocuţia Nappe over the upper menilites.

Micu and Constantin (1993) attach the „*Tarcău type*" sandstone levels to the Kliwa sandstones Unit, and he considers the deposits that follow over them transgressive and separates them as the „*Conglomeratic Unit*", which he assimilates with the Almaşu Burdigalian conglomerates (Săndulescu *et al*., 1995; fide Grasu *et al*. 1999).

The age determinations made by us on the basis of the calcareous nannoplankton on these deposits has indicated an Upper Oligocene – Lower Miocene age.

On Suceava's right bank, in the sector between Nistor and Scorbura Mare brooks, the tectonic relations may be easily deduced in places where the deposits separated by us as Arşiţa Unit come successively into contact with the Lower menilites, Bituminous marls and Kliwa sandstone Units from Poieni anticline.

In the support of the tectonic and not transgressive contact comes even the authors' affirmation showing that the upper disodiles and menilites are present south of Putna River (Bivolărie point). Therefore, during Upper Oligocene the sedimentary basin was functional in the northern segment, as the presence of sedimentation gaps allowing the formation at his level of transgressive deposits has not been proven.

We consider that our interpretation is also sustained by Săndulescu (1984), who shows that on the Marginal folds Nappe area, two sub-units with digitation rank may be separated, being developed in different facies and replacing themselves gradually from north to south: the Pocuţia – Greşu internal digitation and the Bistriţa – Coza external digitation. In this situation, considering the intermediate position of Gura-Putnei semi-window, it is very likely for both subunits to be present.

Vrancea Nappe from Gura-Putnei semi-window

From a structural viewpoint Gura-Putnei tectonic semi-window is characterized by a series of anticline and syncline folds of different directions and with a different degree of tectonics as compared to those from Tarcău Nappe. In Vrancea Nappe the directions of development of the structures are generally N–S, as opposed to the Tarcău Nappe in which the dominant directions are NV–SE. The structures identified in the area, from west to east, are the following:

Poieni anticline. Poieni anticline structure, developed on a N–S direction, closes itself periclinally to the south (Suceava'a right bank), and towards north it continues beyond the Romanian border. Towards west and east it is tectonically limited by the reversed faults Arşiţa and Poieni, respectively.

It consists of Eocene deposits in the axis (Plopu-Bisericani Unit) and Oligocene-Miocene on the flanks (the Lower disodiles, Bituminous marls, Kliwa sandstone, Upper disodiles and menilites and Lower Miocene conglomerates Units). On Suceava's left bank

crops out only the western flank, east of Afinet Hill the structure being covered by Quaternary deposits. On the left bank may be surveyed the pericline closure of the fold, on the Scorbura, Scorbura Mică and Andronic brooks.

The field data allowed the sketching in the lower disodiles of a stratification conformable level (6 m), which we have interpreted as being an olistolithe. In the upper disodiles is also intercalated an olistolithic body of bituminous marls (3 m), but this time discordant, and a few levels of bituminous silto-lutites with fragments of different petrographic constitutions, very well worked (probably by a fluvial network). These observations may argue in our area too, the epiglyptic thrust of Tarcău Nappe (Săndulescu, 1984; Micu and Constantin, 1993).

Vărăria faulted overturned fold. From a geomorphologic point of view it forms Vărăria Hill, with an approximate N-S direction. It consists of the western flank of an anticline folded towards east, whose eastern flank has been strongly laminated. Towards west it is tectonically delineated by the Poieni reversed fault, along which the Plopu-Bisericani Unit from Vărăria faulted overturned fold comes into contact with different Oligocene-Miocene terms from the southern pericline closure of the Poieni anticline. Towards east it thrusts along the Vărăria fault over the Oligocene units of Turanu syncline. The lithologic column of this structure is made exclusively of Eocene units developed in the Doamna lithofacies (Sucevița, Doamna – Vițeu and Plopu-Bisericani Units).

Țuranu syncline. Represents the most eastern structure that crops out in Gura-Putnei semi-window, west of the Putna – Suceava confluence. Towards east, both in the left and right banks of Suceava, the structures are covered by Quaternary deposits. In west it contacts the Sucevița, Doamna – Vițeu and Bisericani Units from Vărăria faulted overturned fold, along Vărăria fault. In the central part the syncline is cut by a NNE-SSV fault, previous to the Vărăria fault. The western flank is affected by secondary folds.

The syncline consists of Eocene deposits belonging to Plopu-Bisericani Unit on the flanks, overlain by Oligocene units (Lower menilites, Bituminous marls, Lower disodiles and Kliwa sandstone).

PALEOGEOGRAPHIC CONCLUSIONS

Although the paleogeographic conclusions are very ambitious, and suppose the existence of some studies in the area that clearly regard this problem, we have engaged on the basis of the existent literature and on our litho-stratigraphic, bio-stratigraphic and tectonic data to issue some ideas regarding this aspect.

The literature we consulted consists of a series of papers regarding the Carpathian flysch that belong to the following authors: Filipescu (1942), Băncilă and Papiu (1960), Joja *et al*. (1963), Contescu *et al*. (1966), Mihăilescu and Contescu (1968), Ionesi (1971), Blondeau (1972), Contescu (1974), Dicea (1974), Hottinger (1977), Alexandrescu and Brustur (1980, 1982, 1984, 1987, 1990), Săndulescu *et al*. (1981), Anastasiu and Jipa (1983), Săndulescu (1984), Micu *et al*. (1987), Grasu *et al*. (1988, 1999, 2002), Ionesi *et al*. (1988), Mária Jámbor – Kness (1988), Săndulescu and Micu (1989), Einsele (1992), Brustur (1995), Florea (1999) and Turtureanu (1999).

The paleogeographic aspects we have signaled are differently present on the deposition areas of the two nappes.

Thus, for the sedimentation area of the Tarcău Nappe may be underlined the following facts:

- during Senonian the uniformity of the sedimentation basin of the external flysch is also maintained in the northern segment, now being deposited the Hangu and Izvor Units on the whole deposition area of the Tarcău Nappe;

- during the Paleocene the sedimentation conditions change due to the activation during the Laramic tectonic movements of a green schists cordillera (Ionesi, 1971; Grasu *et al*., 1988), with a complex sedimentologic and tectonic role;

- during Lower and Middle Eocene the sedimentation covers the deposition area of the Tarcău Nappe with a particular facies characterized by the dominance of arenitic and quartz deposits, that exceed 70-80% of the lithologic column.

The dominant arenitic character of the sedimentation north of Putna River raises a few problems regarding the nature and position of the source area that provided the huge quantities of quartz sand, the paleo-climatic conditions that favored the production of clastic material and the sedimentation basin morphology.

The petrographic and granulometric study conducted by Grasu *et al.* (1988) on Scorbura – Păltinoasa type sandstones shows a mineralogical composition almost identical with that of the Kliwa sandstone (over 90% quartz and cherts) and grain size parameters very close to those of the latter, facts that in the authors' opinion indicates a common platformic source-area for the two petrographic types. Referring to high maturity sandstones, Grasu (1996) launches the idea that the clastic material from the Kliwa sandstone (and therefore that from the Scorbura sandstone also, n.n.) could have derived from metamorphic rocks belonging to the quartz meta-graywacke series of the Dobroudjan cordillera, in the conditions of a very humid subtropical climate, with temperatures of almost 26^0C and precipitations of 5000 mm/year.

The warm climate during Ypresian – Lutetian is consistent with the biostratigraphic information regarding the deposits of the external flysch. Thus the *Nummulites* fauna (with *N. planulatus and N. variolarius*) emphasized in the external flysch deposits (Ionesi, 1999), according to those shown by Blondeau (1972), characterize a climate with average temperatures of 25-27^0C and with a normal salinity of the marine environment. In the same sense the paleo-climate was interpreted by Dicea (1974) on the basis of the agglutinate foraminiferans and by Florea (1999), who considered the nannoplankton associations identified in Sucevița basin.

In the conditions of the Suceava – Putna – Brodina area, if we analyze the tectonic signification of Falcău – Ştef fault, continued to the south by Merța – Bobeica fault, we find a greater movement towards east along this tectonic accident of the western faulted overturned folds (*e.g.* Crucii - Stauina – Sihăstria faulted overturned fold covers completely towards north the Crucii faulted overturned fold). In this situation it is possible that the position in which were formed the deposits of the internal faulted overturned folds (west of the Falcău – Ştef line) to be much more western that the supposed one and that the basin was also alimented from western intra-basinal sources. Yet, regarding the sedimentary material sources, we believe that they are linked to the presence at least of an intra-basinal cordillera similar to that suggested by Contescu (1974) for the Cretaceous internal arenitic facies. Its petrographic constitution must have been similar to that of a green schists cordillera, which in the conditions of a warm and humid climate would have been capable of delivering the huge quantities of quartz sand that led to the formation during the Lower and Middle Eocene of the quartzi sandstones of Scorbura type, 350-390 m thick. Probably the cordillera was situated between the formation areas of the Bâtca – Glodu and Crucii faulted overturned folds;

- during the Oligocene the evolution of our study area enters the paleo-geographic scenario presented by Săndulescu and Micu (1989), with weakly differentiated facieses in the first part when are deposited the lower menilites, bituminous marls and lower disodiles on the entire area and with a slight differentiation at the level of the Kliwa sandstone.

Referring to the sedimentation basin of the deposits belonging to the Vrancea Nappe from the Gura-Putnei semi-window, the following aspects may be shown:

- during the Middle and Upper Eocene is maintained the sedimentation type characteristic to the Doamna lithofacies from Lomul – Scorbura faulted overturned fold, from the front of Tarcău Nappe;

- during the Oligocene appear a series of lithofacial elements that imply the separation of the sedimentation basin of Gura-Putnei semi-window from that of the Tarcău Nappe, as well as a different morphology in relation with the southern areas. Thus in the eastern part of the semi-window, the Oligocene deposits are characterized through the absence of the green rocks elements that occur instead in the western part, in the Arşiţa Unit. This unit is found in tectonic relations with the Oligocene deposits from the eastern area. In these conditions we must imagine two sources of material for the Oligocene basin: an eastern platformic source without green rocks elements and a green schist cordillera in the western area. Considering the absence of green rocks elements in the eastern area of the semi-window, the position of the cordillera must have been more internal, between the Tarcău and Vrancea Nappes and not between the Vrancea and Subcarpathian Nappes. The same idea was remarked by Ionesi (1979) in Humor basin and by Ionesi *et al.* (1988) in Suceviţa basin.

Analyzing the paleo-geographic significations of the litho-stratigraphic, tectonic and bio-stratigraphic data from our study area and from the neighboring ones, we came to believe that the sedimentation area of the deposits belonging to the Tarcău Nappe (at least of those situated west of the Falcău – Ştef line) and possibly also that of the Vrancea Nappe ones, have had a more western position in comparison to the southern neighboring area of Suceviţa. In support of this affirmation comes the tectonic situation, that reveals the much more eastern advance of the western faulted overturned folds north of Putna river, as they cover totally or partially some of the eastern faulted overturned folds (*e.g.* Crucii faulted overturned fold is entirely covered to the north by the western faulted overturned folds, along the Falcău – Ştef line; Bâtca – Glodu faulted overturned fold covers partially the Straja and Lomul – Scorbura faulted overturned folds). The much more accentuated advance of the tectonic units towards east in comparison to the southern regions seems to be a characteristic of the tectonics of the external flysch from this area, aspect that is also suggested by the high degree of covering of the Subcarpathian Nappe by the Tarcău and Vrancea ones.

Another aspect upon which we could draw paleogeographical conclusions refers to the evolution of Suceava valley in the flysch sector from Obcina Mare and Obcinele Brodinei (sensu Barbu, 1976). The corroboration of the litho-structural data with those regarding the distribution of the hydrographic network in relation to the „tectonic-erosional" basins from Nisipitu – Straja area allowed the sketching of the following scenario of paleogeographical evolution:

- during the styrian tectonic phases (Burdigalian – Badenian) the morphographic surface of the Suceava valley relief was sketched, being afterwards completed during the Moldavic movements of Volhynian age. In this stage, the Seletin – Costileva, Ulma – Nisipitu, Brodina – Sadău and Falcău basins were created, separated by ridges of massive quartz sandstones of Scorbura, Lucăceşti or Kliwa type. These functioned as local hydrographic levels up to the end of the Pliocene;

- during Volhynian – Romanian took birth a series of the present tributaries of Suceava, that were effluents to the Sarmatic-Pliocene lakes: Nisipitu, Sadău, Brodina, Brodinioara, Falcău, Cârmaci, Răstoaca and the western segment of Suceava river that flows into Seletin – Costileva lake;

- during Romanian - Pliocene, in the Valahian tectonic phase the sandstone ridges that separated the lake basins were broken and the present course of Suceava river occured. This model explains quite satisfactorily the direction differences registered by Suceava river in certain sectors and may be also extrapolated for other rivers such as Moldova or Putna (form Vrancea).

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