# GEOLOGICAL AND PALYNOLOGICAL CONTRIBUTION TO THE SILURIAN FROM THE NORTH OF MOLDAVIAN PLATFORM

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Abstract: The presence of Silurian in the succesion of the covering deposits stock from the Moldavian Platform is also upholded through the samples from Grănicești - Suceava well. The Samples taken from 2070-2090 m depth snow the presence of the two silurian lithofacies of Rădăuți and of Bătrâneşti in the transition area. There had been identified chitinozoan assemblage with specific species for Ludlowian (Upper Silurian), and acritarch and spores too. The spores assemblage is found for the first time in Upper Silurian from Moldavian Platform.

KEY WORDS: Geology, Palynology, Silurian, North Moldavian Platform

## Geological considerations

In Moldavian Platform covering deposits stack, Silurian is all over the area of this geological unit, excluding the south-western edge of this unit.

Silurian is represented by Wenlockian and Ludlowian epochs (Middle and Upper Silurian), being intercepted by many wells (Hudeşti, Todireni, Botoşana, Rădăuți, Bosanci, Lespezi, Preuteşti, Popeşti). Generally, Silurian is lithologically represented by slaty clays and blackish limestones, with subordinated intercalations of marls, sandstones and dolomites. The entire Silurian lithological complex is fossiliferous. Beju (1962) separates the Silurian lithology into three members (lithological complexes):

- Lower Member, argillaceous, sandstony whom limit with Ordovician is conventionally drawn (1 Popeşti well);

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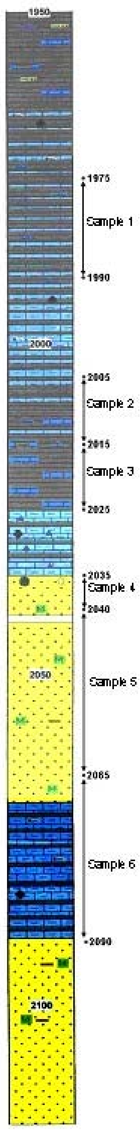


Sample 1 - calcareous slaty clays with limestone intercalations with grey-blackish pyrite traces

Sample 2 - grey-blackish slaty clays with microcrystalline schists and limestones, locally siliceous or argillaceous with pyrite traces

Sample 3 - limy clays with intercalations of microcrystalline schists and limestones locally siliceous or argillaceous, with pyrite traces

Sample 4 - coarse quartzitic sandstone with siliceous cement

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Sample 5 - fine to intermediary sandstone, siliceous quartzitic, with siliceous cement, with pyrite traces

Sample 6 - microcrystalline limestones with grey-blackish shales

Fig. 1. Lithological column of Regal SE1, Suceva well.

- Middle Member, calcareous, (80 Bosanci, 90 Lespezi, 86 Preuteşti wells);
- Upper Member, argillaceous (49, 50, 51 Rădăuți; 1 Popeşti wells).

Ionesi (1994) considers, based on literature data that Silurian descends towards W and S of Moldavian Platform, arguing this idea by data from wells that intercepted it at different points. Thus, in NE of the platform, Silurian was intercepted at Rădăuți-Prut at -70m; at Todireni -241m; Iaşi -336m; Rădăuți -1477m. After the same author (Ionesi, 1994), Silurian appears in two synchronous facies: calcareous facies, in the central and eastern part of the platform, named Bătrâneşti Formation, and argillaceous facies, with graptolites, in NW, named Rădăuți Formation. Both facies offered a rich fauna with brachiopods, trilobites, tentaculites, graptolites, ostracods, bryozoans, bivalves, conodontes (Văscăuțanu, 1931; Macarovici, 1949; Macarovici, 1956; Macarovici, Paghida, 1962; Macarovici, Beju, Olaru, 1965; Macarovici 1971, Iordan, 1975; Ionesi, 1994). Beside this rich fauna coming from the numerous above mentioned studies, Silurian was studied and argued in important palynological-prostistological studies, where important assemblages of chitinozoans, acritarchs and spores (Beju, Dăneț Nurhan, 1962; Macarovici, Beju, Olaru, 1965; Barbu, Ali Mehmet Nurhan, Paraschiv, 1969; Beju, 1972; Patrulius, Iordan, 1974; Iliescu, 1974; Iliescu, 1981).

Rădăuți Formation, predominantly argillaceous, with graptolites, has a smaller extension in the NW of the platform, than Bătrâneşti Formation, in E. It was intercepted and studied in Rădăuți and Botoşana wells, between -1477m and -2700m, with 1223 m width and overstands the Cambrian basement (Ionesi, 1994). The lower part (about 300m) from the lithological column includes limestones, and subordinately grey clays, partially bituminous.

Within grey clay, there was identified a rich fauna of graptolites (*Neodiversograptus nilssoni, Bohemograptus bohemicus, Saetograptus colonus*), tentaculites, ostracods and brachiopods (Paraschiv, Muțiu, 1974) and a rich chitinozoan assemblage, including species from genera: *Ancyrochitina, Conochitina, Lagenochitina, Rhabdochitina, Sphaerochitina*, as well as graptolite sicules and *Scolecodonte* (Beju, Nurhan Dăneț, 1962). Based on these arguments, the age of Rădăuți Formation is considered Wenlockian-Ludlowian (Ionesi, 1994).

### Geological feature of Regal SE 1 well, Suceava

Regal SE 1 well, Suceava was drilled at about 10 km SE of Rădăuți and at 15-20 km S of Siret locality. The succession penetrated by the well belongs to Neozoic, Mezozoic and Palaeozoic (Wenlockian-Ludlowian Rădăuți Formation).

From drilling column data, Silurian was intercepted at 1950 m depth, and the well stopped at about 2118 m.

From the well log data (Figure 1), it comes out that between 1950 m and 2035 m the lithological column includes calcareous slaty clays with prevailing intercalations of grey calcareous micaceous schists, with pyrite traces at 1965 m and 2009 m. The same calcareous slaty clays also appear between 2068 m and 2090 m, with micaceous slaty intercalations at 2077 m.

Between 2035-2068 m and 2090-2118 m (well sole), the lithology starts to change, including grey quartzitic sandstone, coarse at the upper part, sandier, quartzitic at 2035 m depth and also, from 2112 m to the sole. There are mentioned grey calcareous intercalations, cryptocrystalline and microcrystalline with crinoids and algae traces at 2025 m and 2070 m depth. The calcareous clays are fossiliferous, with a generally high amount of organic matter, with unidentifiable black and brown debris, as prove see the frequent pyrite rests.

**Tectonic aspects on Moldavian Platform**

Moldavian Platform represents the westernmost side of Eastern European Platform. It is situated in west and south-west of Ukrainian Shield and Massif, its formations being comprised within its basement.

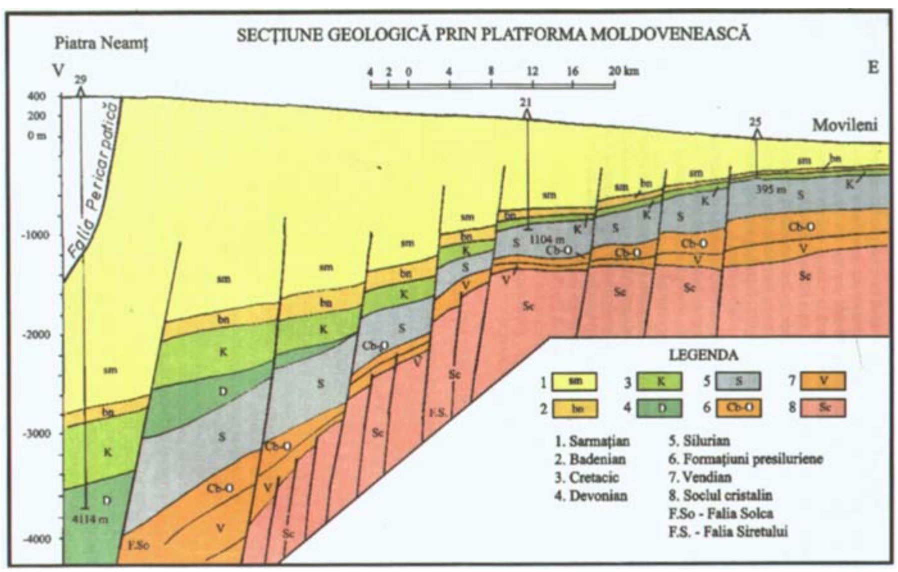


Fig. 2. Moldavian Platform geological profile (after Mutihac, 2004)

Situated in front of Eastern Carpathians, it represents the oldest Romanian geological platform unit, consolidated during Middle Proterozoic. Its consolidation was followed by lifting and weathering processes until Upper Vendian, when it became peneplain. The next stage was a depositional one, when the sedimentary cover formed during three main cycles ended in Meotian. The Upper Vendian-Meotian sedimentary deposits correspond to the platform stage, and they were not folded by the post-Proterozoic orogenic events. Positive and negative geodynamic movements (lifting and falling kinetics) took place at long time intervals, which resulted in some sedimentary basin evolution and in removing of accumulated deposits on the emerged areas.

The main characteristics of the Moldavian Platform tectonics are:

- The progressive falling of the basement and of the sedimentary cover towards west and southwest. The crystalline basement outcrops on Nistru River, also it appears at 900m depth for Prut River and 2000m depth for Siret River (Fig. 1). The western falling under Carpathian Orogene follows a normal N-S fault system, in addition to the other main faults (Siret Fault, Solca Fault, Câmpulung Moldovenesc-Bicaz Fault) (Fig. 3);

- increasing the thickness of the sedimentary cover formations from east towards west, especially for post-Cretaceous deposits, indicating an increasing subsidence of the western side of Moldavian Platform, under the overload of the overthrusting flysch and the molasse napes; the subsidence started in Cretaceous, including several stages. During Middle and Upper Miocene, tectonics were the main sedimentary control factor, thus several depozones were active, initially oriented W-E due to the overthrusting nape overload, then with N-S direction, as result of the subsidence from Vrancea area;

- the shallow deposits show a slight NW-SE dipping (4-8 m/km);

- Carpathian Orogene formations are overthrusting Moldavian Platform edge (about 12-15 km), the newest platform formations caught under the overthrusting line belong to Lower Volhynian. The orogene movement over the platform started in Moldavian tectogenetic phase.

Wallachian (Moesic) Platform is a bit younger than Moldavian Platform, but is characterized by a more powerful faulting system. Numerous ample fractures were observed, some of them oriented E-W. Some more emerged areas were identified comparing to some deep ones. There is a gradual falling between Carpathian Orogene and Wallachian (Moesic) Platform, similar to the Wallachian Platform case. The overthrusting of Carpathian Orogene on Wallachian Platform also took place during the Moldavian tectogenetic phase.

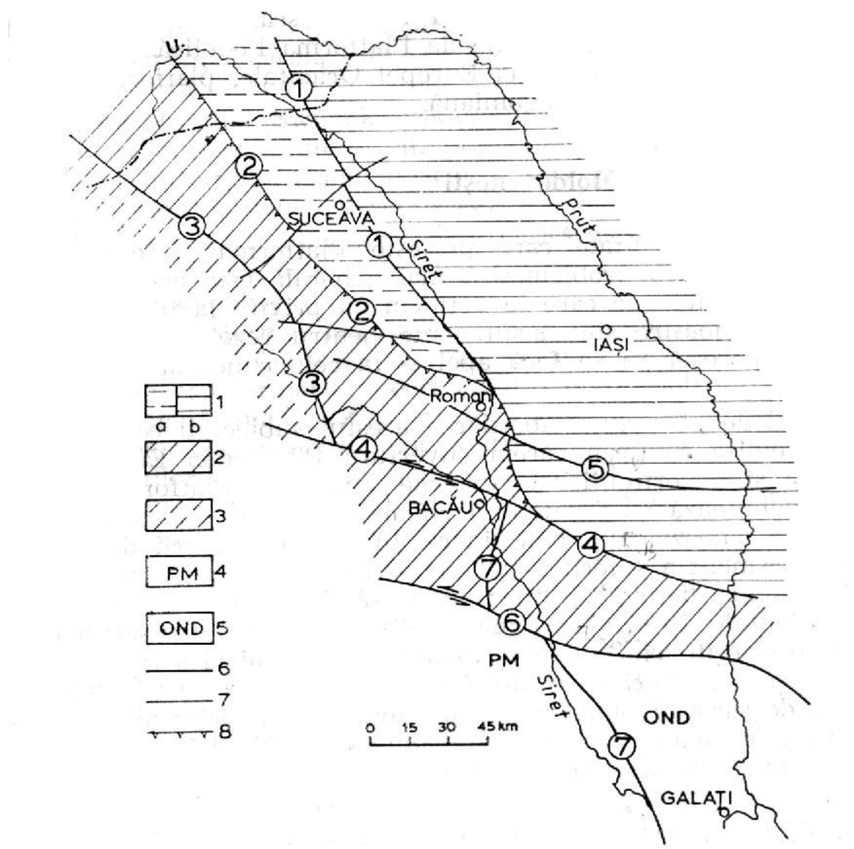


Fig. 3. Tectonic skech of Carpathian foreland in Moldova area (after Săndulescu, Visarion, 1981)

1. Eastern European Platform (Moldavian Platform) (a. Rădăuţi-Paşcani block; b. podolian-moldavian area); 2. Scithian and Central European Platforms; 3. Miechov Depression prolonged; 4. Moesian Platform (PM); 5. N-Dobrogean Orogene (OND); 6. major fractures; 7.faults; 8. overthrust front; (1). Siret Fault (Ustilug-Rogatin Fault); (2). Solca Fault (Rava Ruska Fault); (3). Câmpulung Moldovenesc-Bicaz Fault; (4). Bistriţa Fault; (5). Vaslui Fault; (6). Trotuş Fault; (7). Peceneaga-Camena Fault.

## Material and method

The preparation method is the classical one, as follows:

After the samples were weighted (50g), they were broken up at convenient dimensions, treated with HCl in order to destroy carbonates and to detach the grains from the calcareous cement.

Then they were treated with HF to destroy silicates and the siliceous cement between grains.

Subsequently, all samples were sieved through a 0.8μm to separate the mineral fractions and the larger organic rests that were not desegregated in the previous chemical processes. The remained sample was treated with NaOH solution, 5-10%, for oxidation and clarifying. After each stage of laboratory preparation, the samples were washed with water until they reached a neutral pH. After that, the samples were centrifuged at about 1500 r.p.m., in a heavy liquid with 2.0-2.3 density, including ICd and IK. Then, the samples were washed again; the organic residuum was deposited in a glass decanter and mixed with a liquid gelatin-glycerin fixer, aseptic, where there were drawn drops with a thin glass stick, each drop put on glass lamella. Over this drop there was laid an 18x18mm glass lamella, obtaining the palynological slide, labeled with the name and the symbol of each sample.

The samples thus prepared were systematically analyzed with a biological microscope type "Ergaval", with mobile plate, after X and Y coordination axes. Each observed palynological element was identified, fixing its position in the slide considering X and Y coordinates. Subsequently, the most evident and representative palynomorphs (chitinozoans, acritarchs and spores) were photographed, reanalyzed and redetermined.

## Palynological content of the analyzed samples

### Sample 1 (1975-1990m)

Clays with limestone intercalations with black pyrite leaflets. Four slides were analyzed (1a, 1b, 1c, 1d).

**Chitinozoans**:

*Conochitina simplex* Eis.
*Lagenochitina* cf. *macrostoma* Taug. et De Jekh.
*Angochitina* cf. *capillata* Eis.
*Ancyrochitina fragilis* var. *brevis* Taug. et De Jekh.
*Rhabdochitina magna* Eis.
*Linochitina convexa* Lauf.
*Lagenochitina prussica* Eis.

**Acritarchs**:
*Dactylofusa* cf. *striatifera* (Cramer) Fensome et al.
Acritarchs div. sp.
Filaments

**Slide condition**:

Poor palynomorph content. Many of these appear as incomplete fragments. Difficult interpretation.

**Age**:
Upper Silurian (considering chitinozoans).

**Sample 2 (2005-2015m)**

Clays with limestone intercalations with pyrite leaflets. Four slides were analyzed (2a, 2b, 2c, 2d).

**Chitinozoans**:
*Conochitina lagenomorpha* Eis.
*Angochitina capillata* Eis.
*A.* cf. *capillata* Eis.
*Rhabdochitina magna* Eis.
*Lagenochitina elegans* Beju et Dăneț
*Lagenochitina* cf. *prussica* Eis.
*Angochitina* cf. *echinata* Eis.
*Conochitina elegans* Eis. (biozone species)
*Desmochitina densa* Eis.
*Linochitina convexa* Eis.
*Conochitina decipiens* Taug. et De Jekh.

**Acritarchs**:
*Leiosphaeridia* sp.
Acritarchs div. sp.

**Micro and cryptospores.**

**Slide condition**:

Poor palynomorphs content with many membranous fragments (broken), unidentifiable (probably chitinozoans). Many yellow-brownish fragments (microspores ?) and fragments of amorphous organic matter (AOM), unidentifiable.

**Age**:
Upper Silurian (considering chitinozoans).

**Sample 3 (2015-2025m)**

Clays with limestone intercalations, similar to slides 1 and 2. Four slides were analyzed (3a, 3b, 3c, 3d).

**Chitinozoans**:
*Lagenochitina elegans* Beju et Dăneț (biozone species)
*Rabdochitina tubularis* Umnova
*Conochitina turris* Tang.

**Acritarchs**:
Acritarchs div. sp. (unidentified)

**Slide condition**:
Poorer palynomorphs content than the previous slides (1 and 2), few black amorphous rests.

**Age**:
Upper Silurian (especially considering *L. elegans* species).

**Sample 4 (2035-2040m)**

Quartzitic sandstone, coarse with siliceous cement. Four slides were analyzed (4a, 4b, 4c, 4d).

**Chitinozoans**:
*Angochitina echinata* Eis. (zone species)
*Rhabdochitina* sp

**Acritarchs**:
Acritarchs div. sp.

**Micro and cryptospores.**

**Slide condition**:
Poor palynomorphs content, but with many unidentifiable black fragments (AOM) or broken chitinozoan rests. Some black fragments have sharp peaks, similar to graptolite sicules (inexactly identifiable), as well as Scolecodontes.

**Age**:
Upper Silurian (considering *A. echinata* species).

**Sample 5 (2040-2065m)**

Fine to intermediary siliceous sandstone, quartzitic with siliceous cement, with argillaceous intercalations, and pyrite traces. Four slides were analyzed (5a, 5b, 5c, 5d).

**Chitinozoans**:
*Conochitina* cf. *gordonensis* Cramer
*Cyathochitina kukersiana* Eis. (zone species)
*Ancyrochitina ancyrea* Eis. (zone species)
*Lagenochitina* cf. *L. prussica* Eis.
*Angochitina* cf. *echinata* Eis.
? *Bursachitina* sp.
*Lagenochitina baltica* Eis. (zone species)
*Urnochitina urna* Eis (zone species)
*Conochitina lagenomorpha* Eis.
*Lagenochitina prussica* Eis.
*Lagenochitina* cf. *macrostoma* Taug. et De Jekh.
*Angochitina echinata* Eis. (zone species)
*Rhabdochitina magna* Eis.
*Conochitina decipiens* Taug. et De Jekh.

**Acritarchs**:
*Lophodiacrodium* sp.
*Dactylofusa striatogranulata* Jardiné et al.
Acritarchs div. sp.

**Micro and cryptospores (div. sp.)**

**Slide condition**:
Richer palynomorphs content than the other analyzed samples from this well, considering chitinozoans, acritarchs and the other organic rests. It is the richest sample from this point of view and the most characteristic for Upper Silurian.

**Age**:
Upper Silurian (Ludlowian, Biozone 5, after Sutherland, 1994).

**Typical biozone chitinozoans**:
*Ancyrochitina ancyrea, Cyathochitina kukersiana, Lagenochitina baltica*.

**<u>Sample 6 (2065-2090m)</u>**

Limestones with shales. Four slides were analyzed (6a, 6b, 6c, 6d).

**Chitinozoans**:
*Lagenochitina* cf. *macrostoma* Taug. et De Jekh.
*Conochitina* sp. (cf. *C. intermedia* Eis.)
*Cyathochitina* cf. *kukersiana* Eis.
*Rhabdochitina magna* Eis.
*Sphaerochitina* cf. *sphaerocephala* Eis. (zone species)

**Acritarchs**:
Acritarchs div. sp.

**Micro and cryptospores.**

**Slide condition**:
Generally, the palynomorphs content is poor with many unidentifiable organic rests, probably chitinozoans.

**Age**:
Upper Silurian (considering chitinozoans, see the previous samples).

**Biostratigraphical considerations**

Concerning the biostratigraphical considerations on the analyzed samples, we will limit to discuss only the chitinozoan content because for Silurian stage, these are very important, some of them characterizing specific biozones, which can be correlated with graptolite and conodonte biozones.

For Silurian zonation, there should be analyzed more samples from wells distributed on a more extended area. In this case, we will only do a comparison and a correlation between chitinozoan species we determined and those identified by other authors for Moldavian Platform, then will do a comparison and a correlation with Moesic Platform, from our country, where there much numerous studies on a more extended area.

In Moldavia Platform, Beju, Dăneț (1962) make a detailed study on samples from Rădăuți well (51, 50, 49 holes), Bosanci well (86 hole), Preuteşti well (80 hole), Lespezi (81 hole), Popeşti (1 hole), and, at the same time, having a study on the samples coming from Optaşi well (1 hole) from Moesic Platform. On a comparative look between our results and those coming from the above mentioned wells, there is a large similitude on the determined species. The common species we also met are: *Ancyrochitina ancyrea* Eis., *A. fragilis* Eis., *Angochitina capillata* Eis., *A. echinata* Eis., *Conochitina lagenomorpha* Eis., *C. decipiens* Taug. et De Jekh., *C. elegans* Eis., *Cyathochitina* cf. *kukersiana* Eis., *Lagenochitina baltica* Eis., *L.* cf. *prussica* Eis., *Lagenochitina elegans* Beju et Dăneț, *Rhabdochitina magna* Eis., *Sphaerochitina sphaerocephala* Eis., graptolite spicules, Scolecodontes (*Arabelites* sp.)

All this correlation of the mentioned authors shows that the analyzed samples come from a large area, extended on Moldavian Platform and Moesic Platform. If the cited authors (Beju, Dăneț, 1962) incline to consider genera of *Conochitina* and *Rhabdochitina* (large size forms) belonging to un lower assemblage (Middle Silurian calcareous complex), and the rest of the chitinozoan assemblage (small size forms) belonging to Upper Silurian argillaceous complex, we have a bit different opinion. The entire chitinozoan assemblage we identified in Grăniceşti samples belongs to Upper Silurian (Ludlowian) because both small and large form were found almost in all analyzed slides. Moreover, *Ancyrochitina ancyrea* Eis. indicating Ludlowian, Biozone 5 (Sutherland, 1994), associated with *Lagenochitina baltica* Eis. and *Cyathochitina kukersiana* Eis., appears in Sample 5 (2040-2065 m), besides *Rhabdochitina magna* Eis., one large size form. Then, *Sphaerochitina sphaerocephala* Eis. that we met in Sample 6 (2065-2090 m), at the lower section of the well. This species is mentioned as typical Ludlowian zone species, both in Baltic Shield and in Walles (Paris, 1996). Also, *Urnochitina urna* Eis. from Sample 5 is mentioned as zone species for the end of Upper Silurian (Pridolian), both in Baltic domain (Baltio-Scandinavian Shield) and in North-Gondwanaland domain (Paris, 1996). Also, in Baltic-Scandinavian Shield region, *Ancyrochitina fragilis* var. *brevis* Taug. et De Jekh. is mentioned for Pridolian, which we determined in Sample 1 (1975-1990 m). These are just a few arguments in order to consider all the samples of Grăniceşti well belonging to Upper Silurian (Ludlowian).

If we try a correlation with palynological-protistological zones established for Moesic Platform (Beju, 1972), we find we could consider two biozones, G1 (Valentian-Wenlockian) and G2 (Ludlowian). Among the mentioned species in this biozonation there are few that we also found in the analyzed well. These are: *Conochitina decipiens* Taug. et De Jekh., *C. turris* Taug., *Ancyrochitina* cf. *ancyrea* Eis., *Sphaerochitina sphaerocephala* Eis., which appear in G1 biozone (very rare, but they will abound in G2 upper biozone). In G2 biozone, equivalent to our analyzed well (Ludlowian), besides the cited species, which are more numerous here (Beju, 1972, op. cit.), also appear: *Ancyrochitina ancyrea* Eis., *A. fragilis* Eis., *Lagenochitina elegans* Beju et Dăneț, *Angochitina capillata* Eis. a.o. These two biozones also include numerous acritarch species, as well as our analyzed samples which belong to genera: *Baltisphaeridium*, *Veryhachium*, *Dactylofusa*, and numerous spores of: *Ambitisporites*, *Leiotriletes, Punctatisporites, Retusotriletes, Emphanisporites* (very small forms). We have to remind here that spores appear for the first time in Upper Silurian, all over the planet, because at that time the first terrestrial plants appeared, Psilopsides, which produced the first spores for a reproducing process. These are well preserved within Upper Silurian geological formations, besides acritarchs and chitinozoans and are missing from Lower Silurian. This is a new argument for our opinion, meaning that in our analyzed well from Grăniceşti we are with all samples in Upper Silurian.

As we mentioned above, the identified chitinozoan assemblages come from different domains, belonging to two provinces, a northern Baltio-Scandinavian one and a southern one.

Concerning the chitinozoan origin, the species of genera *Ancyrochitina* and *Lagenochitina* show an african origin, and the species of genus *Angochitina* have a northern, european origin. Species of genus *Conochitina* are universal. Here, on Romania territory, especially in Moldavian Platform, there are many species commun to both provinces, and the stratigraphical division based on provinces is difficult because they are mixed (Iliescu, Taugourdeau, 1981). According to the origin of the identified species, we could have a more extended correlation between different other regions and our working area. But there are necessary many more samples from wells set on a much larger area. However, we limit to the above presented facts.

**Conclusions**

As a result of the analysis of Regal SE1, Suceava we could have the following conclusions:

- In order to have a more precise analysis, there are necessary much more samples, coming from cores and not already sieved;

- The analyzed samples must come from more wells, dispersed on a larger area in order to observe the extension and the relationships between both Silurian formations, Rădăuți Formation (argillaceous facies with graptolites) and Bătrâneşti Formation (calcareous facies).

- Both Silurian formations are synchronous, their intercrossing/crossword would be possible when thick limestone intercalations appear within clays, as the case of Grăniceşti well, between 2070-2090 m depth.

All the analyzed samples from Regal SE 1, Suceava well are Ludlowian (Upper Silurian) considering the chitinozoan assemblage, with Ludlowian zone species, acritarch assemblage and spores assemblage, the last one appearing for the first time in Upper Silurian, at the same time with the appearance of the first terrestrial plants, Psilopsides, spores producers.

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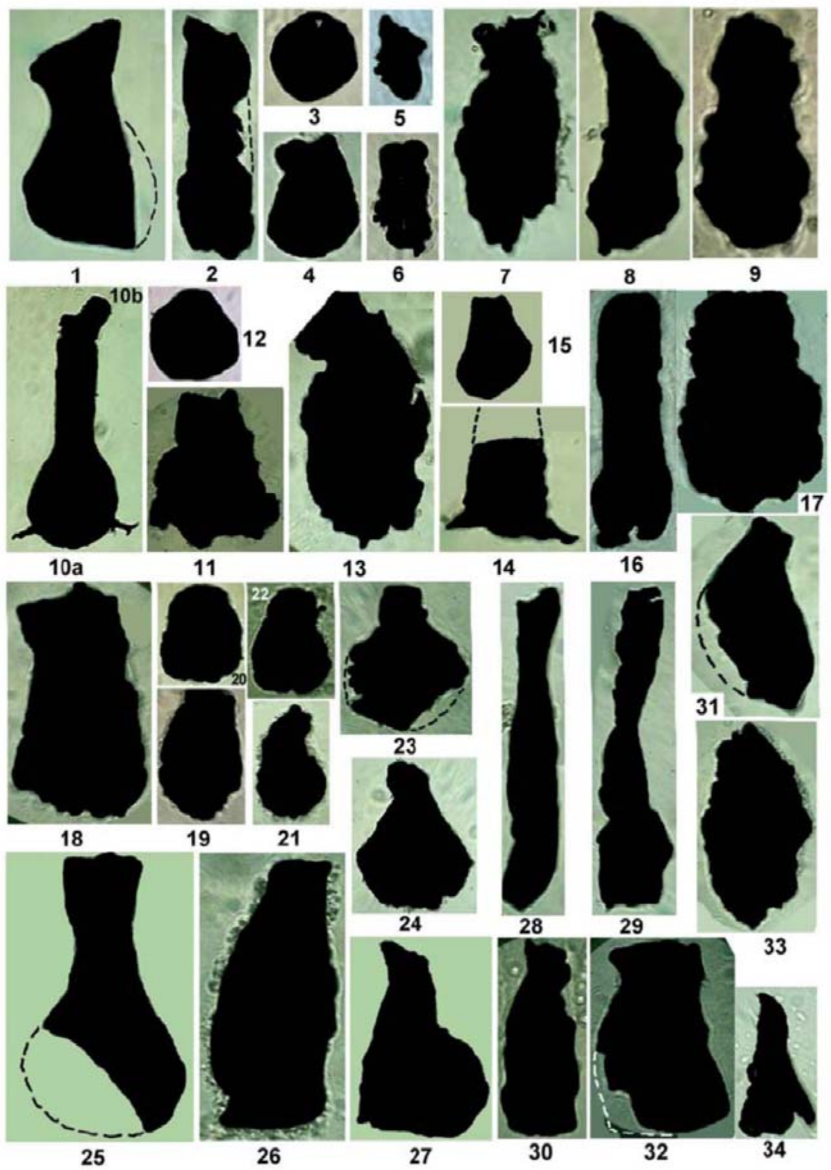
**Plate explanation**
**Plate I**

1. *Lagenochitina* cf. *macrostoma* Taug. et De Jekh
2. *Conochitina elegans* Eis.
3. *Desmochitina densa* Eis.
4. *Conochitina lagenomorpha* Eis.
5. *Linochitina convexa* Lauf.
6. *Angochitina capillata* Eis.
7. *Angochitina* cf. *A. echinata* Eis.
8. *Rhabdochitina tubularis* Umnova
9. *Lagenochitina elegans* Beju et Dăneț
10 a. *Ancyrochitina ancyrea* Eis.
10 b. *Cyathochitina* cf. *C. kukersiana* Eis.
11. *Cyathochitina kukersiana* Eis.
12. *Desmochitina* sp. (cf. *D. densa* Eis.)
13. *Angochitina* cf. *capillata* Eis.
14. *Ancyrochitina* cf. *fragilis* Eis. (fragment)
15. *Lagenochitina prussica* Eis.
16. *Conochitina elegans* Eis.
17. *Urnochitina urna* Eis.
18. *Conochitina decipiens* Taug. et De Jekh.
19. *Lagenochitina* cf. *L. prussica* Eis.
20. *Conochitina lagenomorpha* Eis.
21. *Angochitina* cf. *A. echinata* Eis.
22. *Lagenochitina prussica* Eis.
23. *Lagenochitina* cf. *macrostoma* Taug. et De Jekh.

24. *Lagenochitina* cf. *macrostoma* Taug. et De Jekh.
25. *Lagenochitina baltica* Eis.
26. *Angochitina echinata* Eis.
27. *Lagenochitina* cf. *macrostoma* Taug. et De Jekh.
28. *Rhabdochitina magna* Eis.
29. *Rhabdochitina magna* Eis.
30. *Conochitina turris* Taug.
31. *Sphaerochitina* cf. *S. sphaerocephala* Eis.
32. *Conochitina decipiens* Taug. et De Jekh.
33. *Angochitina echinata* Eis.
34. *Scolecodonta* (*Arabelites* sp.)

Figures: 1-4; 7-9; 11, 12, 16-28; 30-33, x250 increased
Figures: 6, 10a, 10b; 14-16; 29; 34, x400 increased

PLATE I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