Post-Depositional Evolution of the Carbonate Reservoir Systems of the Moesian Platform, Romania*

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Abstract

A sedimentological analysis has been performed to illustrate the post-depositional (diagenetic) evolution of the reservoir architectures component of some Moesian Platform structures. Several methods, grain size and shape analyses, microstructures examination, cathodoluminiscence and U.V. fluorescence studies, have been applied.

Specific post-depositional processes acted differently, spatially and temporally, and have been identified, as follows: differential compaction and illuviation of matrix, syn-depositional bioturbation, micritization, vadose- and submarine-cementation, polymorphic transformations, recrystallization (by aggradation), authigenesis of calcite, dolomite and pyrite, pressure solutions, and joints/fractures. Recrystallization is the most frequent, is selective and affected the matrix, peloides, intraclasts and bioclasts. The process is never complete and not symmetrical. Microstylolites are the effect of pressure solution and cover the boundaries between the layers. Dolomitization was a recurrent process in telogenesis and mesogenesis stages. The effective and total porosity of the studied reservoirs are subject to these processes that specifically controlled modifications of "grain-support" and pore space, within three diagenetic stages: incipient burial (eogenesis), uplift (telogenesis) and, respectively, progressive burial (mesogenesis).

The hydrocarbon dynamics, either from source to reservoir bodies or inside reservoirs, could be considered a complex process, mainly controlled by pore space configuration and by the relationship between the time of hydrocarbon maturation and the evolution of each process modifying pore space. The prediction of hydrocarbons in dolomitic reservoirs, which hosted large voids, should be considered with the depositional model.

Geological Setting

The Moesian Platform lies between the Carpathian foredeep and the Danube. It is bordered to the northeast by the North Dobrudgean Promontory. The Moesian Platform consists of Paleozoic, Mesozoic and Tertiary (Upper Miocene and Pliocene) clastics and carbonates. The local thickness of the sediments is more than 10,000m, while in the northeastern part, in the vicinity of the Focsani Depression, the thickest sedimentary sequence in Romania, more than 15,000 m, is developed (Figure 1).

Four major sedimentary cycles, separated by more or less extended unconformities, have been identified: Cambrian - Middle Carboniferous, Permian - Upper Triassic, Upper Liassic - Senonian and Badenian - Quaternary. The studied formations (s.l.) are component units of the Jurassic - Cretaceous macrosequence, being related to the IIIrd cycle of sedimentation that controlled the evolution of this area and consisting of carbonate deposits, evaporites and clastics; the inferred age is upper Jurassic (Malm) - lower Valanginian.

At the end of Early Cretaceous the Valanginian - Tithonic sequence was composed of fringing reefs (from Serdanu to Ghergheasa), barrier reef/patch reefs (from Brâncoveanu to Ungureni) and lagoonal facies toward east. The (exclusive) carbonate sequences developed in the central- western area of Moesian Platform were uplifted and became emergent during Barremian time.

Lithofacies types component of the Lower Cretaceous formations are represented by the following:

1) In the central - eastern zone (Talpa - Titu - Periş - Domneşti - Videle): biolithites (boundstones); and mudstones-wackestones-packstones-grainstones, in bioclastic/pelletal/intraclastic varieties, specific for higher-energy environments; and

2) In the central - western zone (Hârleşti - Siliştea - Gliganu - Titu - Preajba): associations of mudstones – wackestones - packstones and clastic limestones (calcarenites-calcisiltites- calcilutites), suggesting lower-energy basins (relative to the above), are very common; this zone was not a subject of our study (Figure 2).

During Late Jurassic - Early Cretaceous, sedimentation took place in a relatively shallow-water basin, controlled by periodic base-level changes and active subsidence. The depositional systems were represented by coastal and shelf environments, in which carbonate platforms, either isolated (patch reefs) or elongated, dissected (barrier reefs), progressively developed. Behind reefs, peculiar environments (as regarding salinity conditions) evolved from normal saline to hypersaline. This great diversity of depositional environments explains the petrographic spectra.

Petrographic Types and Depositonal Settings

Recent contributions, based on complex analyses of a great number of core samples (Popescu et al., 2000), specified that sedimentation processes acted across two types of carbonate platforms:

1) Reef platforms - with reservoirs related to reef bodies and flanks, having high secondary porosities (5-23%) and containing small hydrocarbon fields (4-250 t/day); main occurrences: at Petreşti, Brâncoveanu, Serdanu, Corbii Mari, Poiana, Ungureni, Periş, Blejeşti, Videle, Talpa, Bălăria;

2) Pelagic platforms - open shelves, gently dipping and relatively shallow (<300-400 m); the component facies types usually have lower porosities (3-7%) and host many, but small, hydrocarbon fields (2-30 t/day); main occurrences: at Vultureanca, Drăghineasa, Humele, Dumbrava, Ştefan cel Mare, Izvoru.

Skeletal Framework and Pore Space

The skeletal framework is represented by the reef core and diversified by the relationships between the allochemical particles (intraclasts, peloids), crystals (dolomite, calcite), bioclasts and other (gravelly/sandy clasts, terrigenous-extrabasinal material).

The pore space of the analyzed petrotypes and, consequently, the reservoir quality is determined by medium-high porosity (3-7%), controlled by primary pores; i.e., interparticle, intrabioclastic, shelter, intrapeloidic or skeletal/growth framework, and secondary pores (intercrystalline, joints, dissolution pores) (Figure 3).

Due to the diversity of the pore system and to relationships between different kinds of particles, the effective porosity is increased and, consequently, the dynamic permeability could reach very high values.

Diagenetic Processes and Related Effects

The porogenesis and poronecrosis stages involved in evolution of pore space available for hydrocarbon migration and accumulation spanned a long time, between the period of sedimentation and of progressive burial (more than 3000 m), and were identified by integrating mineralogical, petrographical, paleontological and structural data (as revealed by specific diagenetic products). Specific diagenetic processes, physical, chemical and biochemical in character, that acted differently, spatially and temporally, have been identified as follows: differential compaction and illuviation of matrix, syndepositional bioturbations, micritizations, vadose and submarine cementations, polymorphic transformations, recrystallization (by aggradation), authigenesis of calcite, dolomite and pyrite, pressure solutions, and joints/fractures.

The effective and total porosity of the reservoirs is directly subject to processes that specifically controlled modifications of "grain-framework" and pore space within three diagenetic stages: incipient burial (eogenesis), uplifting (telogenesis) and, respectively, progressive burial (mesogenesis) (Figure 4). The multistage character of diagenesis and, accordingly, the repetitive control of porogenesis and poronecrosis is suggested either by very different features of authigenic phases to be found as cements, isolated crystals within matrix, pseudomorphosis, remobilizations along joints and pressure sollution (stylolitic) surfaces, all these being mineralogically calcite, dolomite, glauconite or pyrite. Among these processes, dolomitization, pressure solution and joint systems allowed us to establish a valid model of post-depositional (diagenetic) evolution.

Dolomitization acted as a recurrent process and should not be generalized areally or temporally; it started during telogenesis, after the first stages of uplift of the primary platform, and ended much later, during progressive burial (as suggested by two dolomite generations (I- II); also, several associated effects have been identified. As a result, dolomitization acted selectively and through which:

- "primary" structures could be preserved, or
- "primary" structures could be completely destroyed.

The effects of dolomitization should be gradually traced and interpreted (i.e., from crystals to aggregates and sequence); the interpretations should not be transferred from one scale/order of magnitude to another; moreover, in the case of studied formations the syndolomitization porosity was not significant. So, dolomitization should not be regarded as an exclusively porogenetic process; many times Mg-metasomatic substitution and formation of secondary porosity could destroy the primary pore system, and, so, many effects are poronecrotic in character. The evaluation of the dolomitization effects in a reservoir (and the interpretation of the occurrence of dolomite in carbonate bodies) should take into account numerous factors: paleosol fabric, texture, fluid composition, substitution rate and time.

Pressure solutions surfaces (stylolites) represented either migration paths for solutions, or barriers, and developed before and after dolomitization. Their formation suggests a burial of around 2000 m and pressures of 400- 500 bar.

Joint systems developed during different stages of diagenetic evolution and greatly increased effective porosity of the affected grain framework. Joints were often identified as important migration paths for fluids; the last systems that cross the last generations of authigenic minerals (glauconite, calcite III, dolomite II), suggest that petrographic systems underwent repetitive stages of burial and uplift. Besides seismic and geotectonic data, joints strongly demonstrate that the Moesian basement had a rigid behaviour, being fractured into many blocks that were activated even during post-Mesosoic times. The hydrocarbons migrated within reservoirs during many stages and localized in interparticle/intercrystalline pores, along crystalline heterogeneities (i.e., those developed during calcite aggradation), in dissolution pores and along joints/fractures.

The above-mentioned diagenetic processes actived within three diagenetic stages: incipient burial (eogenesis, uplift (telogenesis), and, respectively progressive/deep burial (mesogenesis).
The curve in Figure 5 shows the migration of the lower Valanginian sediment surface in the basin during upper Valanginian to upper Cretaceous (Senonian), demonstrating the repetitive effects of first burial/uplift and the effects of the later burial, below upper Valanginian-Senonian sediments, up to 1000 m. Under these circumstances the deposits continued to undergo diagenetic and authigenic processes of several generations (e.g. calcite I, II, III, dolomite I, II, etc.).

The base level fluctuations that controlled the evolution of sedimentation and diagenesis suggest that the main porogenetic (and poronecrotic) effects can be grouped in three different stages: highstand (HST), transgressive stand (TST) and lowstand (LST) and are also recognized at other chronostratigraphic levels of Moesian Platform.

Conclusions

- No evaluations of hydrocarbon potential of any reservoir could be made without an estimate of the pore space quality and its relationship to authigenetic processes (silicifiation, calcitization, dolomitization, glauconitization, etc.), with cementation, recrystallization, metasomatic replacement or pressure solutions; for a correct assessment of the pore types, an integrated, viable post-depositional model should be developed, one that is presumably different in the case of carbonate reservoirs (relative to the siliciclastic ones);

- The main porogenetic indicators to evaluate the quality of carbonate reservoirs are:
  - Petrography of carbonate platforms and related microfacies (e.g., Dunham, Flugel);
  - Interfacies relationships between reef core, platform and flanks;
  - Estimate of the effects of eo-, meso- and telogenetic processes and events in pore systems generation;
  - Joint/fracture generations and their timing;
  - Consideration of replacement dolomite/dolomitic cement ratio;

- Any prediction of hydrocarbon potential of a reservoir should first take into account a depositional model. The intercrystalline and vuggy (dissolution-related) pores are the most common for carbonate reservoirs, and could develop either before or after dolomitization stages; in dolomitic reservoirs, the inherited porosity could strongly control permeability;

The hydrocarbon dynamics, either from source to reservoir bodies or inside reservoirs, could be considered a complex process, mainly controlled by pore space configuration and by the interplay between the time of hydrocarbon maturation and the evolution of each process modifying pore space.

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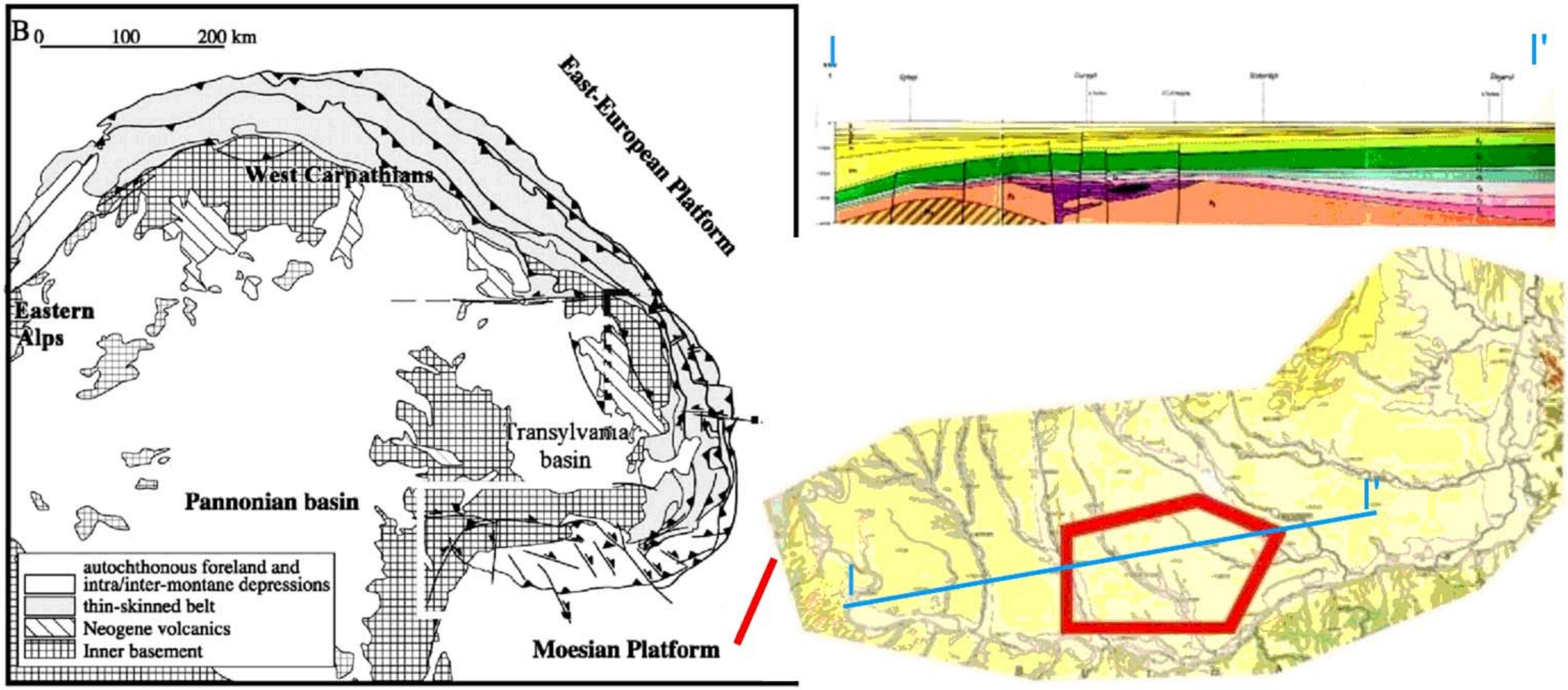

Figure 1. Location of the Moesian Platform in relation to the Carpathians and Pannonian Basin.

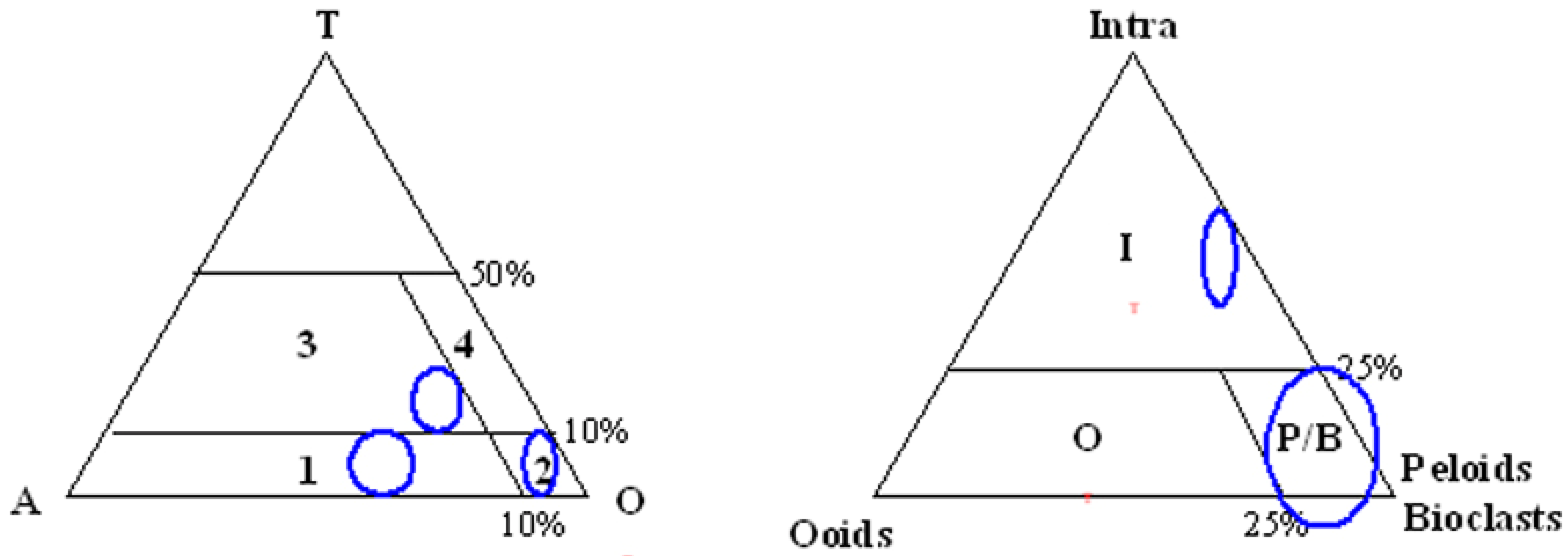

Figure 2. Carbonate petrotypes (modified after Folk, 1962); 1. allochemical 2. orthochemical, 3. hybrid, with terrigenous material, 4. hybrid-orthochemical, with terrigenous material. The diagrams do not include biolithites. The fields in circles correspond to the identified petrotypes.

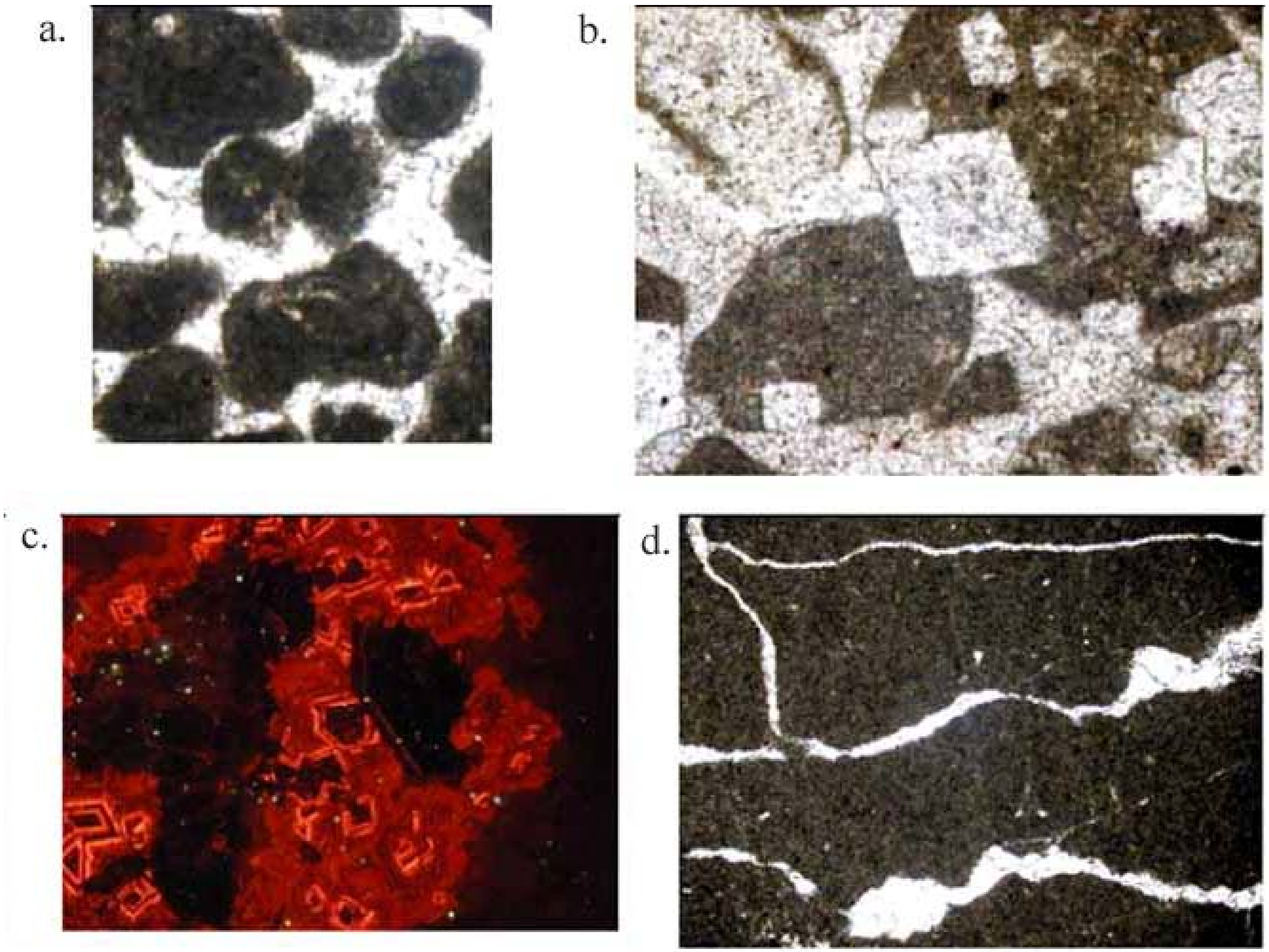

Figure 3. Photomicrographs. a. Peloids and spar cement. b. Secondary euhedral dolomite. c. Zoned dolomite and pores in CL light. d. Joints in micritic limestone.

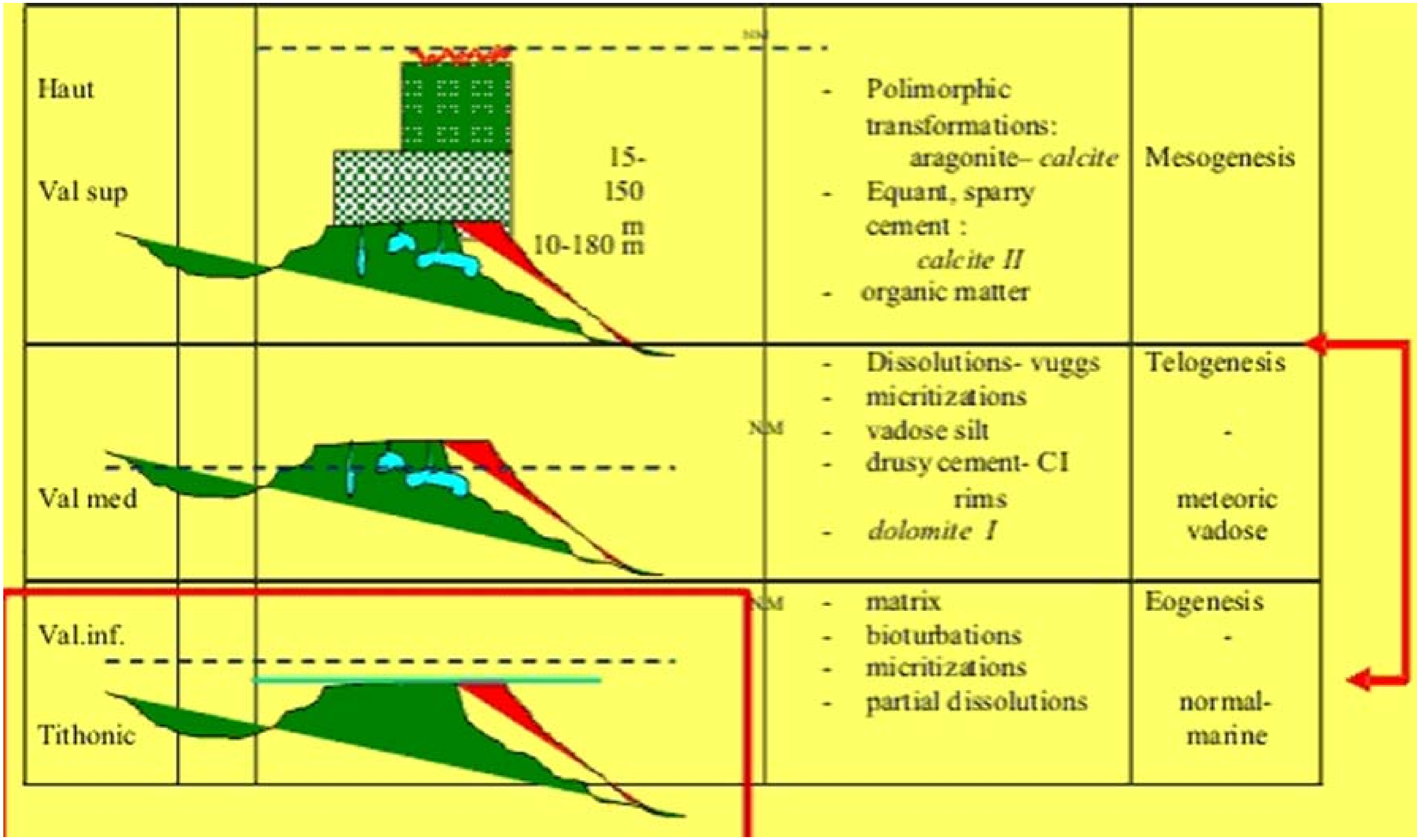

Figure 4. Evolution of reef surface related to sea level change and diagenetic processes.

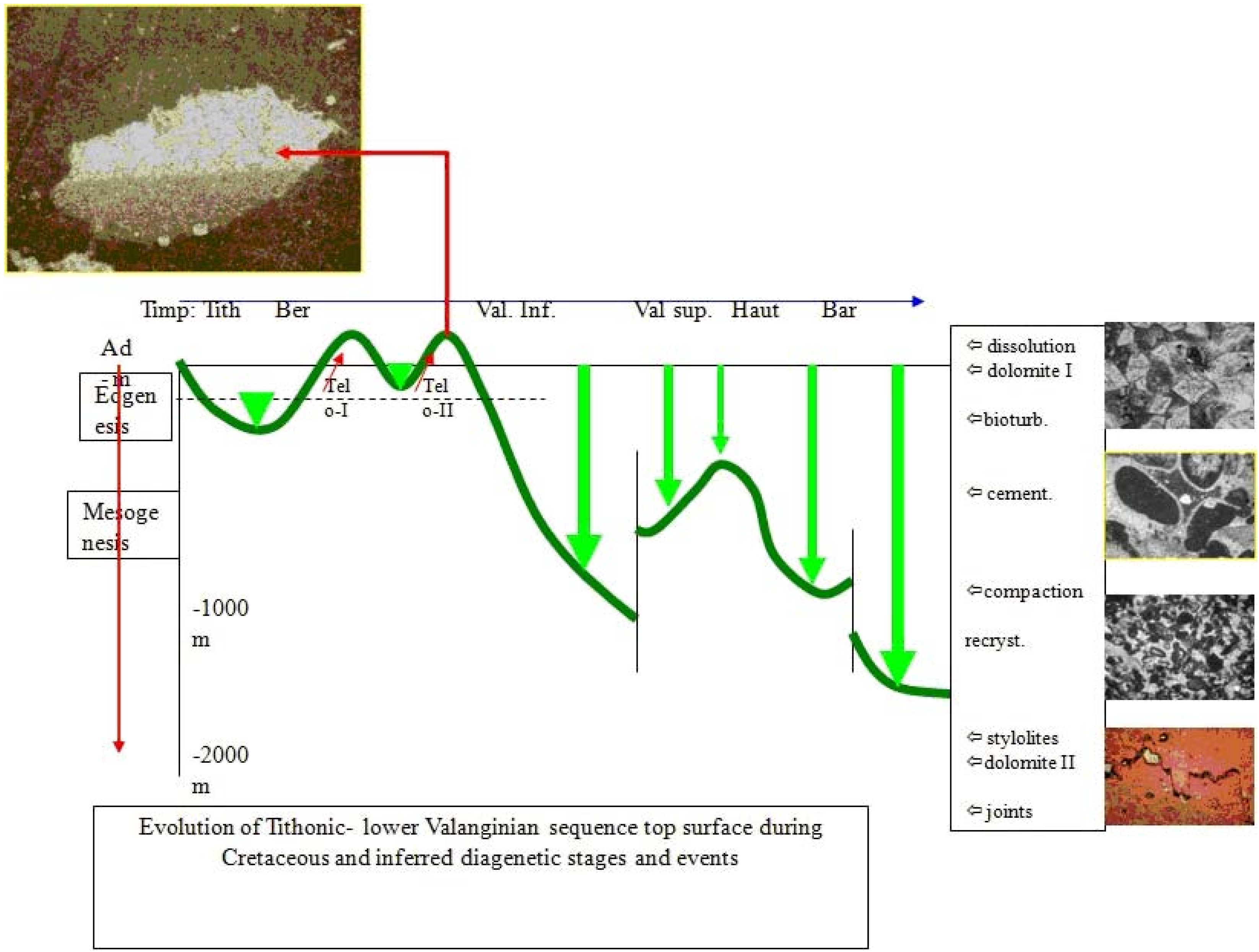

Figure 5. Evolution curve of diagenetic stages and processes.