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UPPER MIOCENE KARST COLLAPSE STRUCTURES OF THE EAST COAST, MALLORCA, SPAIN

**PODORNE STRUKTURE V ZGORNJEMIOCENSKEM KRASU
NA VZHODNI OBALI MALLORCE (ŠPANIJA)**

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Izvleček

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Pedro Robledo Ardila & Luis Pomar: Podorne strukture v zgornjemiocenskem krasu na vzhodni obali Mallorce (Španija)

V obalnih stenah na Mallorci (Zahodno Sredozemlje) so obsežni izdanki zgornjemiocenskih karbonatnih kamnin. Na vzhodni obali otoka prekrivajo grebenški sklop mesinijski plitvodni karbonati. Tod so v zgornjemiocenskih kamninah številne paleokraške podorne strukture. V apnenec Santanyí so vrezane strukture v obliki črke V, kar kaže na udiranje stropov jam, nastalih v spodaj ležečih grebenških sklopih. Glede na model je mogoče nastanek nekaterih izmed teh kraških podornih struktur povezati z zgodnjimi diagenetskimi procesi, na katere so vplivale pogoste spremembe nivoja morske gladine. V času nizkega nivoja morske gladine je sladkovodni tok izdolbel jamski sistem v bližini vodne gladine na tak način, da je raztapljal aragonit v frontalnem faciesu in skupke koral v obstoječih lagunskih plasteh. Ta jamski sistem se je razvijal v bližini površinske erozijske baze. Med kasnejšim dvigom morske gladine so plasti notranjega dela šelfa prekrile predhodno zakraselo jedro grebena in izvenlagunske plasti. Vrezane »V« strukture je lahko povzročila povečana teža odloženih plitvodnih karbonatov, zaradi česar je prihajalo do gravitacijskih udiranj jamskih stropov v času, ko te plasti še niso bile popolnoma strjene.

Ključne besede: paleokras, podorne strukture, zgornji miocen, apnenec Santanyí, koralni greben, Mallorca, Balearsko otočje, Španija.

Abstract

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Pedro Robledo Ardila & Luis Pomar: Upper Miocene karst collapse structures of the east coast, Mallorca, Spain

In the sea cliffs on the Mallorca Island, Western Mediterranean there are extensive outcrops of Upper Miocene carbonate rocks. On the Eastern coast of Mallorca, the reefal complex is overlain by a Messinian shallow-water carbonate complex. There are abundant Paleokarst collapse structures. The Santanyí Limestone beds are affected by V-incision structures produced by roof collapse of caverns developed in the underlying reefal complex. According to the model, the origin of some of these karst-collapse structures may be related to early diagenetic processes controlled by high-frequency sea-level fluctuations. During lowstands of sea level, freshwater flow might have create a cave system near the water table by dissolution of aragonite in the reef front facies and coral patches existing in the lagoonal beds. This cave system developed near the subaerial erosion surface. During subsequent rise of sea level inner-shelf beds overlaid the previously karstified reef-core and outer-lagoonal beds. Increase of loading by subsequent accretion of the shallow-water carbonates might have produced V-incision structures by gravitational collapse of cave roofs when these beds were still not completely consolidated.

Key words: Paleokarst, collapse structures, Upper Miocene, Santanyí Limestone, coral reef, Mallorca, Balearic Islands, Spain.

INTRODUCTION

Paleokarst systems affecting carbonate rock present a pronounced lateral and vertical spatial complexity that results from a complex history of formation. Most of the known karst systems are epigenetic and they are the result of near-surface karst processes during periods of subaerial exposure and later burial compaction and diagenesis. Scale, porosity types and spatial complexities of these paleokarst systems depends on the carbonate rock solubility, paleoclimatic conditions, lowering of base level either by tectonic uplift or sea-level fall and time of subaerial exposure. Uplift, in addition, commonly induces fracturing and faulting that further control karst development.

Ascertaining and predicting paleokarstic heterogeneities within carbonate rock are strategic to field development and optimum production. With current subsurface methods, however, most of the smaller-scale stratigraphic architecture and diagenetic facies are difficult to define. Predictive models for exploration and development are best made from outcrop studies of well-exposed examples. Accuracy for prediction of these models depends on the detailed understanding of the genetic factors controlling the geometries, scale, pore networks and spatial complexities of these potential karstic reservoirs.

GEOLOGICAL SETTING

Upper Miocene carbonate rocks in Mallorca are very well exposed on the sea cliffs and they allow detailed studies of facies architecture and diagenetic patterns. They are fairly flat-lying limestones and dolomites, having undergone slight tilting and flexure associated with normal and strike-slip faulting during the Late Neogene to Middle Pleistocene times (Fig. 1).

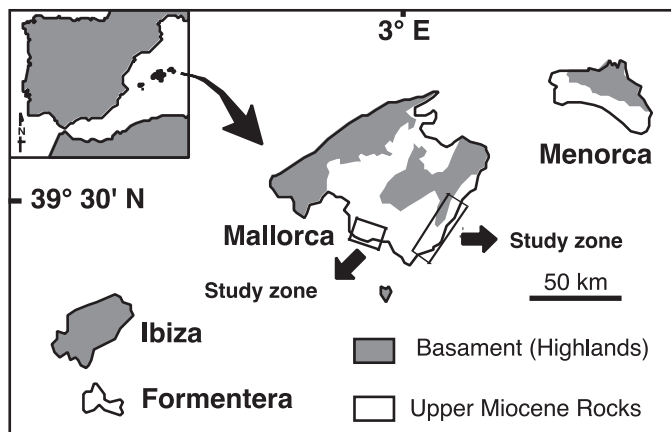


Fig. 1: Geographical location and geological setting.

Upper Tortonian and Lower Messinian carbonates consist of reef complexes that prograded across platforms surrounding paleo-islands. These carbonate build-ups consisted of shelf-margin tracts of coral reefs with fore-reef slopes and back-reef lagoons. Progradation of these reef systems produced a fairly simple vertical sequence of lithofacies. The open-shelf (shallow-basin) lithofacies is overlain by fore-reef-slope litho-

facies, which is overlain by reef core, which, in turn, is overlain by lagoon lithofacies. Complexities on the stratal patterns and facies architecture of these reef platforms resulted from changes on

carbonate production and accommodation related to high-frequency sea-level fluctuations (Pomar & Ward, 1999).

On the eastern coast of Mallorca, the reef complex is overlain by a Messinian shallow-water carbonate complex, the Santanyí Limestone, which consist of miliolid packstone and grainstone with vertical root traces (mangrove swamps), stromatolitic bindstones and mudstones, and cross-bedded oolitic grainstone (Pomar et al., 1996).

Paleokarst collapse structures are abundant in the Upper Miocene rocks of the eastern coast of Mallorca. The Santanyí Limestone beds are affected by V-incision structures (Fig. 2) produced by roof collapse of caverns developed in the underlying reefal complex. Although some papers mention (Esteban & Klappa, 1983) or describe these structures (Fornós et al., 1988; Fornós, 1998), no precise genetic model exists up to the present.

KARST COLLAPSE STRUCTURES: ORIGIN AND DEVELOPMENT

Recent unpublished work on the reefal complex cropping out on the southern Mallorca sea cliffs allow to create a genetic hypothesis to explain the origin of similar V-incision structures developed in the back-reef lagoon beds. According to this working hypothesis, the origin of these karst collapse structures may be related to early diagenetic processes controlled by high-frequency sea-level fluctuations, the same sea-level fluctuations that control the facies architecture of the carbonate platform.

Facies architecture

Accretional units, within the reef platform, represent high-frequency depositional sequences formed in response to high-frequency sea-level fluctuations. Up to four bundles (or systems tracts), which are related to specific parts of the sea-level cycle, can be defined from characteristic changes in the hierarchical stacking patterns among these accretional units.

- The “lowstand” systems tract (LST) formed during the initial sea-level rise, after the lowest point of the sea-level cycle. It mainly consists of prograding reef-core, with thin forereef-slope and open-shelf lithofacies without significant lagoonal beds.
- The aggrading systems tract (AST) corresponds to the most rapidly rising part of the sea-level curve, and it is volumetrically the most important. The AST is characterized by well-developed barrier reefs and thick aggradation without backstepping in all depositional systems, from the lagoon to the open shelf (shallow basin). The AST lagoon lithofacies overlies the LST and consists of landward onlapping strata.
- The highstand systems tract (HST) is related to the highest part of sea-level cycle. It consists of prograding reef core, with forereef-slope lithofacies wedging out basinward and volumetrically condensed open-shelf lithofacies. Lagoon beds commonly are absent (because of non-deposition or erosion during subsequent fall of sea level).
- The offlapping systems tract (OST) formed during falling sea level. It consists of prograding and downstepping reef lithofacies (fringing reefs without significant forereef-slope lithofacies), which downlaps on to the distal-slope and open-shelf lithofacies of the previous HST. There is no lagoon lithofacies, and the open-shelf lithofacies is volumetrically condensed.

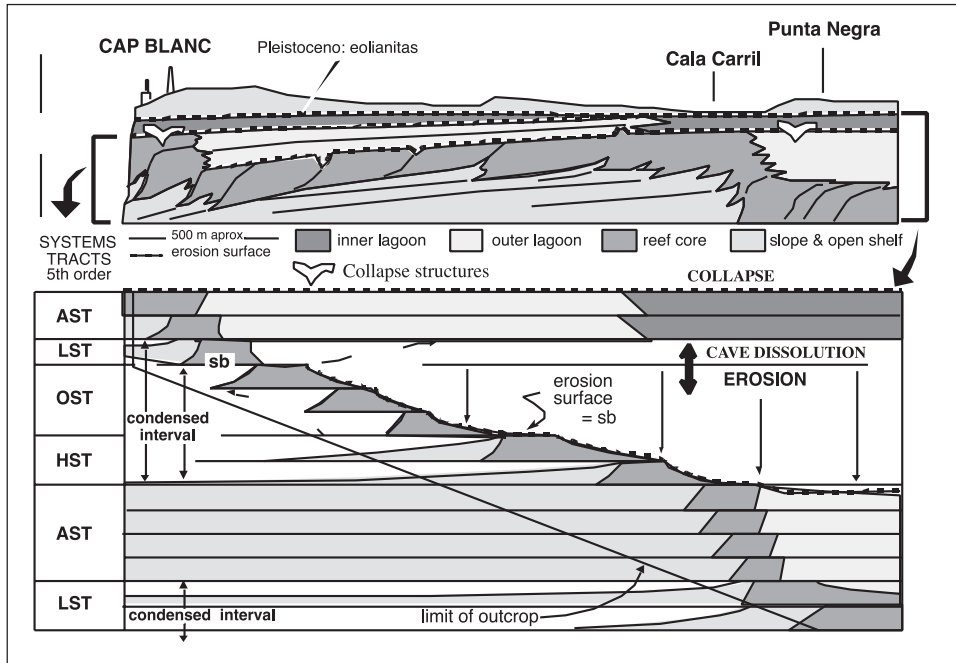


Fig. 2: Collapse structures in the lagoon beds of the Reef complex and Weeler diagram.

Origin of the Karst-Collapse Structures

During lowstands of sea level (Fig. 3) fresh-water flow might have created a cave system near the water table by dissolution of aragonite (mainly corals) in the reef front facies and coral patches existing in the lagoon beds (just behind the reef tract) of the previous AST (Fig. 2). This cave system developed near the subaerial erosion surface. During subsequent rise of sea level, inner lagoon beds overlaid the previously karstified reef-core and outer-lagoon beds. Increase of loading by subsequent accretion of the lagoon beds might have produced V-incision structures by gravitational collapse of cave roofs when these beds were still not completely consolidated (Fig. 3).

According to this hypothetical model, these collapse structures will preferentially occur in the reef core and back-reef settings of the aggrading systems tracts. It is worth mentioning that this structure occurs in a similar setting, at top of an aggrading segment of the platform. Even though much of the lithological complexity of these platforms is beyond the resolution of current subsurface methods, the causal relationship between depositional and early diagenetic processes here hypothesized is relevant to predicting and analysing the heterogeneous distribution of rock properties in reef-complex reservoirs.

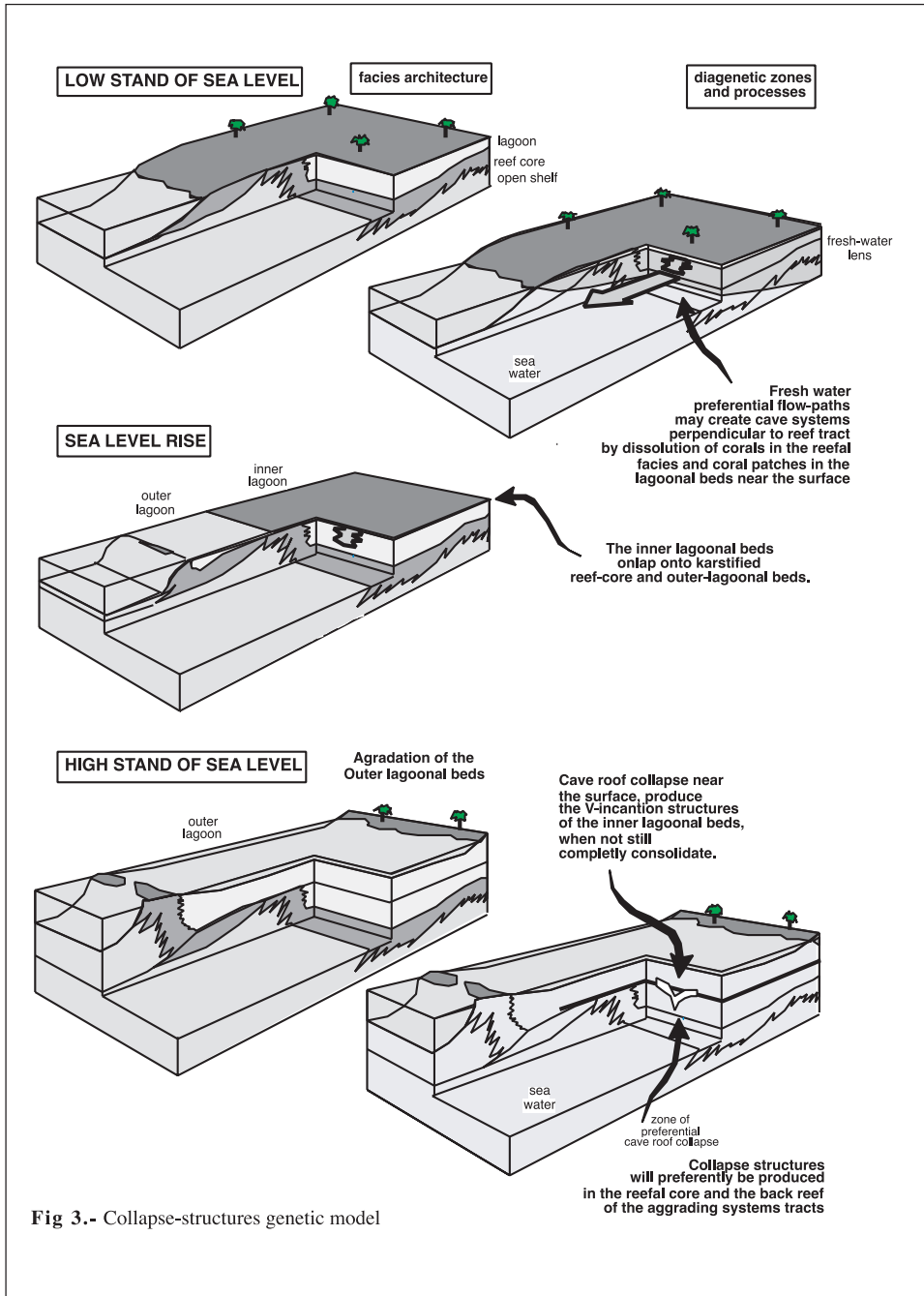


Fig. 3: Collapse-structures genetic model.

BIBLIOGRAPHY

- Esteban, M., Klappa, C., 1983: Subaerial Exposure, chapter 1, pp. 1-96 in P. A. Sholle, D. G. Bebut & C. H. Moore, eds, Carbonate Depositional Environments, American Association of Petroleum Geologists, Tulsa, Oklahoma, USA.
- Fornós J. J., Ginés, A., Ginés, J. and Pomar, L., 1988: Paleokarst collapse breccias in the uppermost Miocene of Mallorca Islands, Spain, Abstract, 9th IAS Regional Meeting of Sedimentology - Leuven, Belgium.
- Fornós. J., 1998: Karst collapse phenomena in the Upper Miocene of Mallorca (Balearic Islands, Western Mediterranean), Acta Geologica Hungarica, Vol. 42/2.
- Pomar, L., Ward, W. C. y Green, D.G., 1996: Upper Miocene Reef Complex of the Lluçmajor area, Mallorca, Spain, pp. 191-225 in: Franseen, E., Esteban, M., Ward, W.C., and Rouchy, J.M. eds.: Models for Carbonate Stratigraphy from Miocene Reef Complexes of the Mediterranean regions, SEPM Concepts in Sedimentology and Paleontology Series, n. 5.
- Pomar, L., and Ward, W. C., 1999: Reservoir-Scale Heterogeneity in Depositional Packages and Diagenetic Patterns on a Reef-Rimmed Platform, Upper Miocene, Mallorca, Spain, American Association of Petroleum Geologists Bulletin; 83: 1759-1773.

PODORNE STRUKTURE V ZGORNJEMIOCENSKEM KRASU NA VZHODNI OBALI MALLORCE (ŠPANIJA)

Povzetek

V obalnih stenah na Mallorci (Zahodno Sredozemlje) so obsežni izdanki zgornjemiocenskih karbonatnih kamnin, ki omogočajo podrobno preučevanje genetskih procesov, ki so vzrok sestavi faciesa kot tudi diagenetskimi vzorcem. Gre za plosko ležeče apnenice in dolomite, ki so bili podvrženi rahlemu gubanju, tudi v obliki fleksure, od poznega neogena do srednjega pleistocena.

Zgornjetortonjske in spodnjemesinijske karbonate sestavljajo grebenski sklopi, ki so napredovali preko plitvin, ki so obkrožale nekdanje otoke. Gre za dele koralnih grebenov na meji šelfa s predgrebenskimi pobočji in notranjimi lagunami. Na vzhodni obali Mallorce prekrivajo ta grebenski sklop mesinijski plitvodni karbonati - apnenici Santanyí.

V zgornjemiocenskih kamninah na vzhodni obali Mallorce so številne paleokraške podorne strukture. V apnenice Santanyí so vrezane strukture v obliki črke V, kar kaže na udiranje stropov jam, nastalih v spodaj ležečih grebenskih sklopih. Na podlagi najnovejših raziskav teh karbonatnih platform je mogoče predložiti model, ki pojasnjuje nastanek teh »V« vrezanih struktur. Glede na ta model je mogoče nastanek nekaterih izmed teh kraških podornih struktur povezati z zgodnjimi diagenetskimi procesi, na katere so vplivale pogoste spremembe nivoja morske gladine, torej iste spremembe, ki so določale tudi zgradbo faciesa te karbonatne platforme. V času nizkega nivoja morske gladine je lahko sladkovodni tok izdolbel jamski sistem v bližini vodne gladine na tak način, da je raztapljal aragonit (predvsem korale) v frontalnem faciesu in skupke koral v obstoječih lagunskih plasteh (takoj za koralnim grebenom).

Ta jamski sistem se je razvijal v bližini površinske erozijske baze. Med kasnejšim dvigom morske gladine so plasti notranjega dela šelfa prekrile predhodno zakraselo jedro grebena in izven-

lagunske plasti. Vrezane »V« strukture je lahko povzročila povečana teža odloženih plitvovodnih karbonatov, zaradi česar je prihajalo do gravitacijskih udiranj jamskih stropov v času, ko te plasti še niso bile popolnoma strjene.