A Field Trip Report

An Overview of the Paleomorphology and Paleogeography of Tortonian–Messinian Carbonates in the Almería-Níjar Basin, Southern Spain

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Introduction

Southern Spain is famous for its beautiful beaches that usually receive a flock of Spanish and European tourists during the summer. The region has Mediterranean climate without much rain but a lot of sunshine for majority of the year. It has mild and wet winter but in some places it can be very dry and has limited vegetation cover only. The climate is a contributing factor to the preservation of spectacular rock outcrops, which provide beautiful landscapes, outstanding scenes, and more importantly, valuable field laboratory to learn sedimentology and stratigraphy. One such region is Almería Province that has several small basins, including the Almería-Níjar Basin (Figure 1).



Figure 1. Location map and places (viewpoints) mentioned in the text (satellite images source: Google)

The Almería-Níjar Basin has extensive outcrops of Upper Miocene carbonate complex that lie on the foothill of Sierra Alhamilla and also along the coast. Recently, a group of geoscientists from Repsol visited some of the Upper Miocene carbonate outcrops to see their large scale geometries and then to get a closer look at their lithofacies. The visit was aimed mainly to observe paleomorphology that can be used as analogs for seismic interpretation purpose. The Upper Miocene carbonate outcrops of the Almería-Níjar Basin are unique because their present geometries are still similar to their paleomorphologies during the time of deposition.

Regional Setting

The Almería-Níjar Basin is part of a series of Neogene sedimentary basins that lie within the ENE-WSW-orientated Betic Cordillera (Figure 2a). The Betic Cordillera is a mountain chain that together with the Moroccan Rif, form the western edge of the larger, Alpine Mountain range (Figure 2b). The basin occupies the present-day low-lying area bound by Sierras Alhamilla and Cabrera to the north and by Sierra de Gador to the west. To the southwest, south and east, the basin is bound by the Mediterranean Sea (Figure 3). The southern to southeastern part of the basin includes Sierra Cabo de Gata, a hilly terrain that consists of Miocene volcanic rock exposed along the coastline. The northern to western hills that bound the Almería-Níjar Basin are all composed dominantly of metamorphic rocks, which form the basement of the Betic Cordillera.

The Almería-Níjar and other associated Neogene basins developed as a result of emplacements of stacked thrust sheets during the Alpine orogeny, which started in the Late Mesozoic (e.g. Monie *et al.*, 1991). By Early to Middle Miocene, the emplacements of the thrust sheets already took place in the internal zone of the Betics, leading to the uplifts of Sierras Nevada and de los Filabres (Figure 3). At the time, The Almería-Níjar Basin was not yet separated from the Tabernas, Sorbas and Vera Basins (Braga *et al.*, 2003), so they formed a single deepmarine depocentre, which received sediment supply from the emerged Sierras Nevada and de los Filabres.

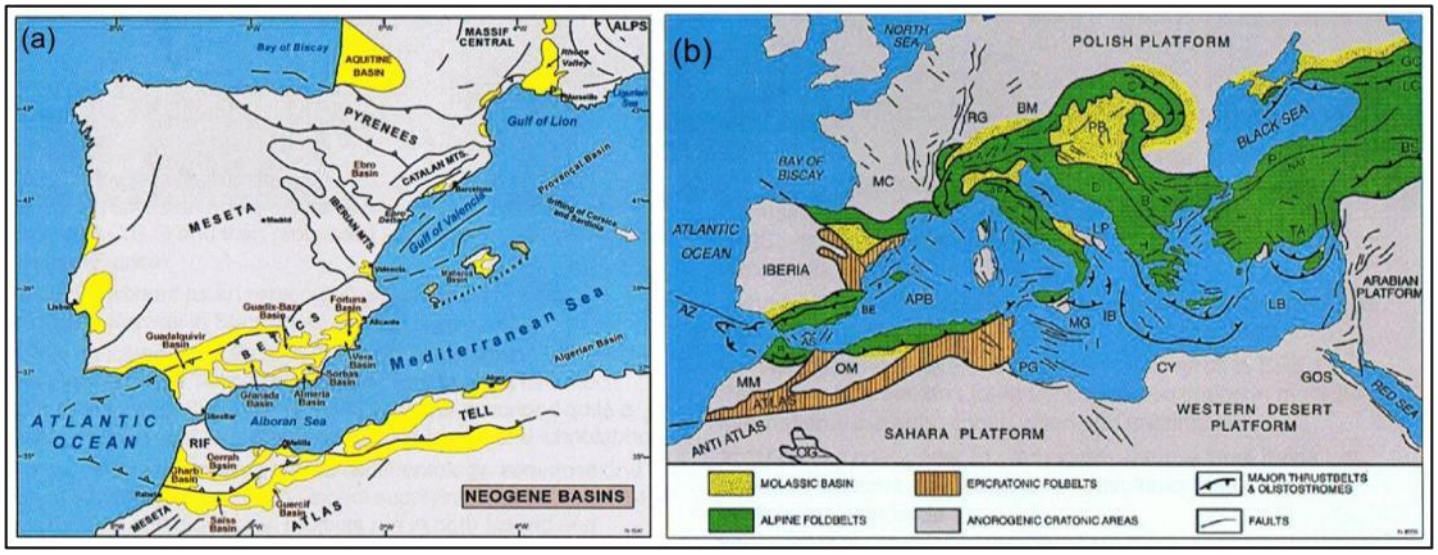


Figure 2. (a) Neogene basins within the Betic Cordillera of SE Spain. (b) Alpine mountain chain/foldbelts (after Esteban and Gerard, 2010)

At approximately 11 Ma (late Serravallian), compressional tectonics initiated strike-slip fault movements that intersected the internal zone of the Betic Cordillera at several places (Sanz de Galdeano, 2000). One of them cuts through the Almería-Níjar Basin, creating a fault zone called Carboneras Fault. The Carboneras Fault trends NE-SW but it turns north at the eastern flank of the Sierra Cabrera and continues along the Palomeras Fault Zone (Figure 3). The compressional tectonics and associated strike-slip movements re-arrranged the initially single depocentre into more restricted, but interconnected basins. This re-arrangement was due to the emergence of Sierras de Gador and Alhamilla at 7 Ma and then followed by Sierra Cabrera at 5 Ma (Braga *et al.*, 2003). The uplifts shifted the basins into shallower water setting at the end of Tortonian and continued further in the Middle Messinian, when sabkha condition prevailed in the entire Mediterranean Basin. The entire region eventually emerged in the Pleistocene to form its present-day continental setting.

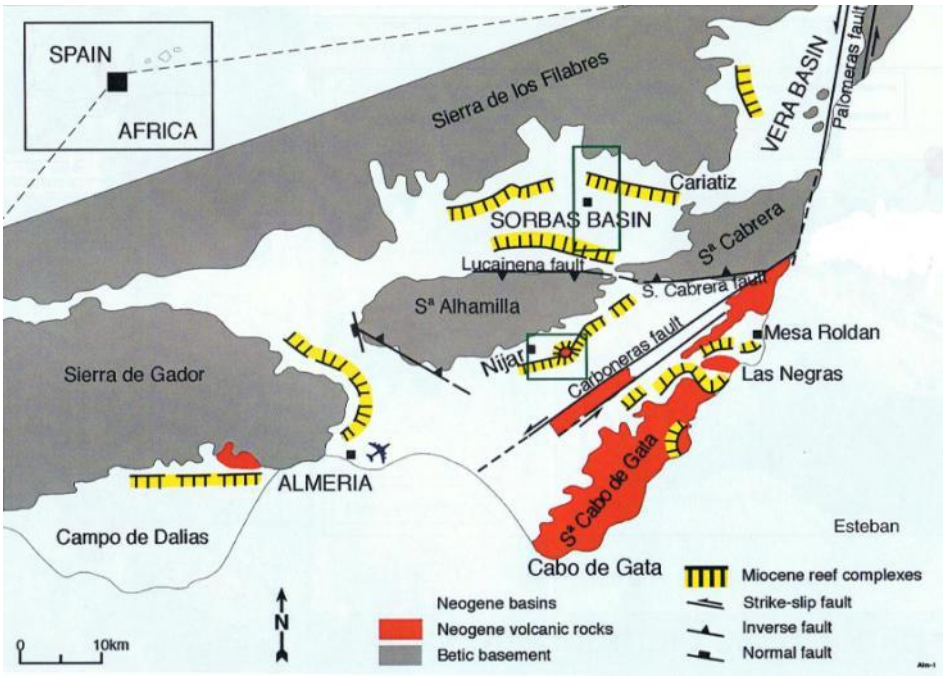


Figure 3. Geological units and structural elements of the Almería region (after Esteban and Gerard, 2010).

Tortonian (Upper Miocene)–Pliocene Stratigraphy

The Lower and Middle Miocene stratigraphy of the Almería-Níjar and other associated Neogene basins in the region consist mostly of deepwater turbidites and pelagic marls (Fig. 4). The turbidites were sourced from the emerged Sierras Nevada and de los Filabres and were transported by fluvial network over paleocoastline situated at the foot of the emerged hills. The deepwater condition remained until early Tortonian (10–8 Ma), but during the late Tortonian (8–6 Ma), it changed when Sierras Alhamilla and de Grados began to emerge, leading to the deposition of carbonate platforms and reefs on the basin margin. The Upper Tortonian consists of biogenic calcareous sandstones, turbidites, pelagic marls, algal limestones, reefs and conglomerates that were deposited unconformably above the older sediments (Figure 4).

From Tortonian to Messinian, the change in depositional environment occurred conformably and shallower marine deposits were accumulated in the region. During the Early Messinian, pelagic marls were deposited in the basin setting while reefs developed on the basin margin. The Lower Messinian deposits also include diatomites and olistolites. In the Middle Messinian, gypsum was deposited across the region and locally, some coral reefs were also deposited (Esteban *et al.*, 1996). In the Late Messinian, littoral limestones, ooids, stromatolites and marls were deposited above the Middle Messinian gypsum. Erosion of the upper part of the Messinian section occured in the

Pliocene, creating an unconformity that separates the overlying Lower Pliocene littoral limestones and pelagic marls from the underlying Messinian deposits. The Lower Pliocene section is separated from the overlying littoral bioclastic sandy limestone of the Upper Pliocene by an unconformity and since the Pleistocene onward, continental sediments are being deposited in the region as the area emerged completely to its present setting.

Níjar Platform

Níjar Platform is located to the southeast of Sierra Alhamilla, occupying an area of approximately 30 km² and is oriented in NE-SW direction. The viewpoint at the Níjar outcrop is located at approximately 36° 57' 09" N and 02° 11' 15" W. From the viewpoint toward the NE, platform and slope geometries are visible (Figure 5a). Looking toward North, peak and valley morphologies can be seen at the edge between the platform and the slope (platform break) (Figure 5b). These morphologies are called *spur* and *groove*, with spur being the peak and groove the valley. The spur is made of upper slope and reef framework facies (Figure 5c), while the groove is composed of bioclastic sands that were trapped during their transport from the platform towards the lower slope/basin by wave activities. In this locality, the reef framework is composed of red algae, while the lower part of the slope consists of layered, white and soft chalks that form distal slope facies (Figure 5d).

La Gorra

La Gorra quarry is located in the Sierra Cabo de Gata domain at approximately 36° 57' 02" N and 01° 57' 52" W. The outcrop faces south and is oriented E-W and it consists of marine calcareous sandstones (Figure 6a). The outcrop is about 10 m high and it most likely comprises several high order sequences (probably 4th order sequence). The lower part of the outcrop shows sedimentation direction towards the east or southeast while the upper part shows a reverse sedimentation direction. A conspicuous sequence boundary (SB5) can be seen on the upper part of the outcrop where it is

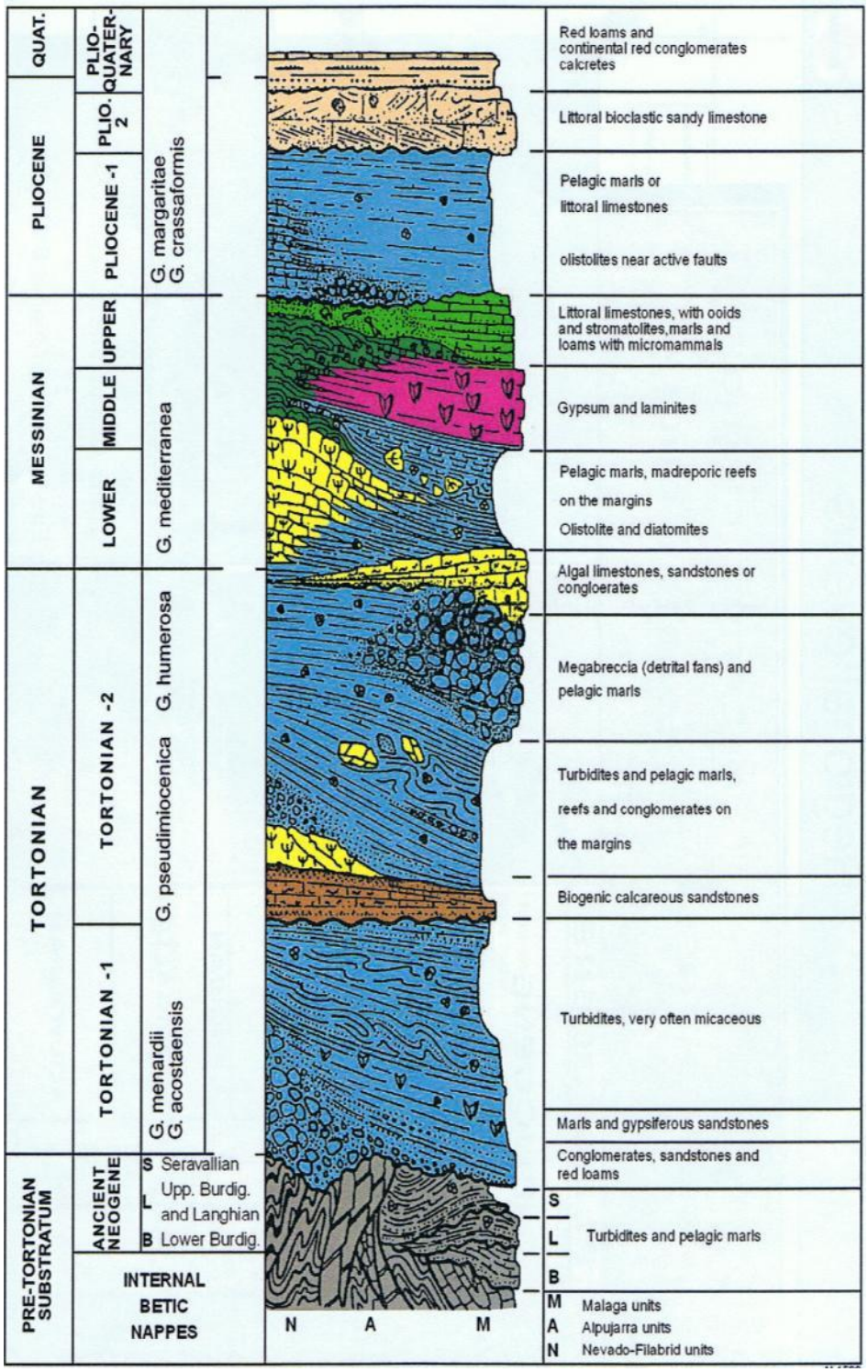


Figure 4. Regional stratigraphic column of the Almería-Níjar Basin (after Esteban and Gerard, 2010).

possible overlain by red-coloured paleosol. The calcareous sandstones contain a lot of bryozoan fragments and some burrows can also be seen (Figure 6b).

Los Muertos Beach

Los Muertos Beach is situated to the south of Sierra Cabrera and is located at coordinates 36° 57' 41" N and 01° 54' 00" W. The outcrop (Figure 7) is composed of Upper Miocene karstified carbonate rocks, which are overlain by Pliocene carbonate skeletal sandstones. The Pliocene unit is well-bedded and it shows downlap configuration towards the east (left side of the figure). The two rock units are seperated by an erosional contact, which represents the Messinian Unconformity. Note the V-structure (karst-collapse) below the Messinian Unconformity (right side of the figure) that was formed during relative sea level fall of over 200 m (after Esteban and Gerard, 2010).

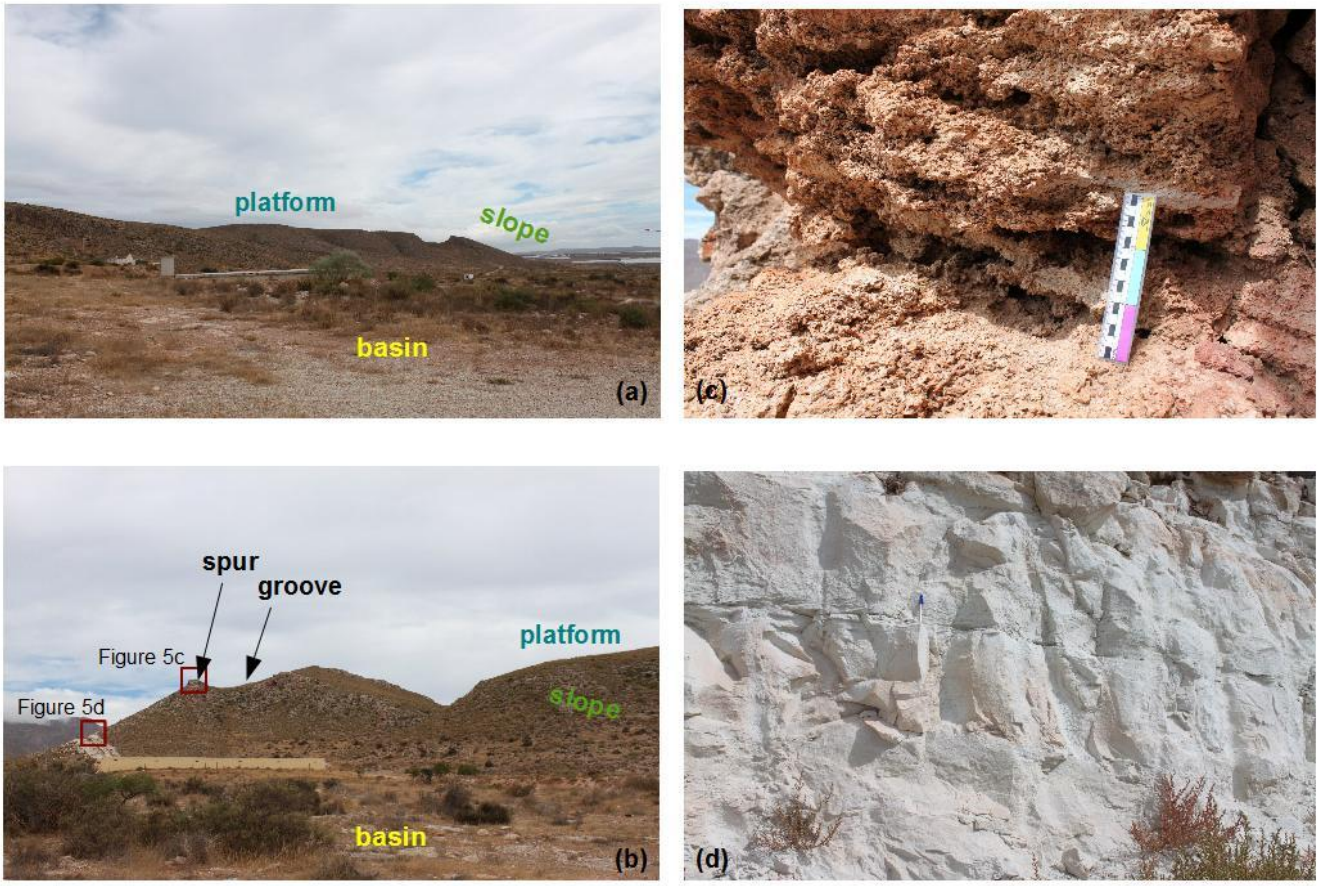


Figure 5. The Tortonian carbonate outcrops near Níjar. (a) Platform, slope and basin are visible from the viewpoint (view toward NE). (b) Spur and groove near the edge of the platform, before the platform changes into slope (view toward N). (c) Chalk outcropped in the lower part of the slope. (d) Outcrop of corals located on the upper part of the platform.

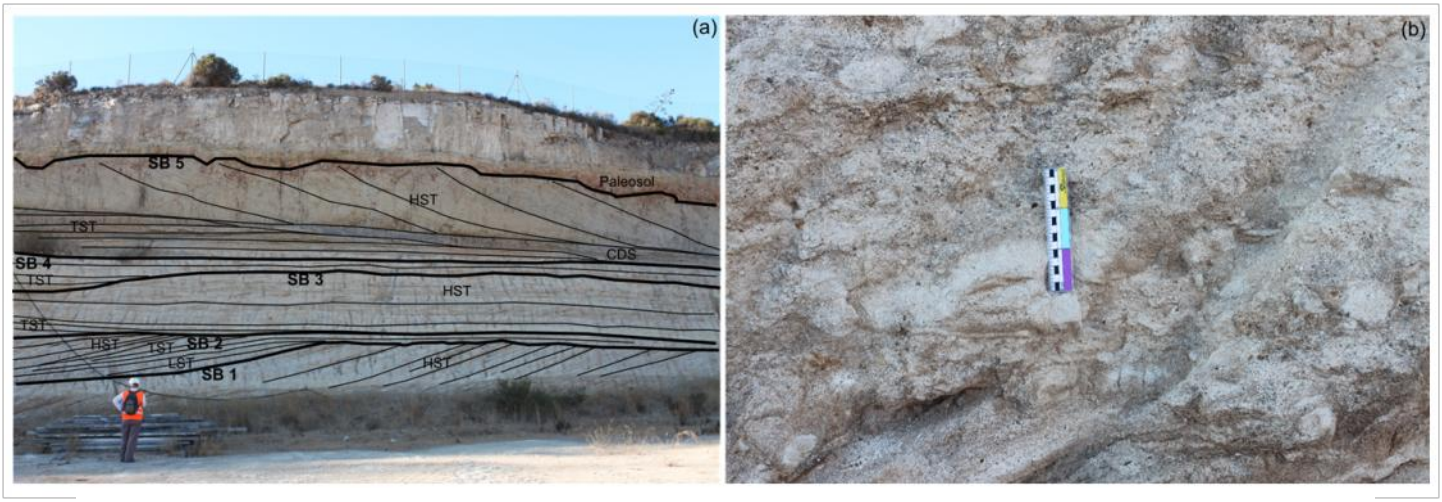


Figure 6. (a) Calcareous sandstones outcrop in La Gorra quarry and interpreted sequence stratigraphic surfaces on the outcrop. (b) Burrows in parts of the La Gorra outcrop.

Las Negras-La Molata

Las Negras Beach/La Molata section is located in the Sierra Cabo de Gata domain. The viewpoint is located at approximately 36º 52' 21.80" N and 02º 00' 42.00" W, on a hill that lies to the north of the La Molata section (Figure 8a). The section consists of carbonate-dominated Tortonian and Messinian rocks, which are sitting unconformably on the Serravallian–Tortonian volcanic basement. The lower to middle Tortonian section consists of muddy packstones (DS1A) and a fining upward sequence (DS1B), which is bound by a sequence boundary at the top (Figure 8b). The upper Tortonian sequence is comprised of conglomerates and volcanic detritus (DS2) and is overlain by Messinian reef cores and talus sequence. The topmost of the section is interpreted as a Terminal Carbonate Complex (TCC) by Franseen *et al.* (1998) and this sequence consists of stromatolites boundstones and oolites grainstones.

Summary

The Upper Miocene carbonate outcrops in the Almería-Níjar Basins consist of many types of morphology including platform with spur and groove, slope, karst-collapse feature (V-structure) and reef complex. The

outcrops also display stratigraphic surfaces that can be recognised on seismic scale such as clinoforms, downlap, onlap and truncation surfaces. They proved to be useful as analogs for interpreting paleomorphology and stratigraphic surfaces on a seismic section.

Acknowledgements

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Figure 7. Los Muertos' outcrop showing the Upper Miocene and Pliocene rocks seperated by Messinian Unconformity. The Pliocene shows downlap configuration.

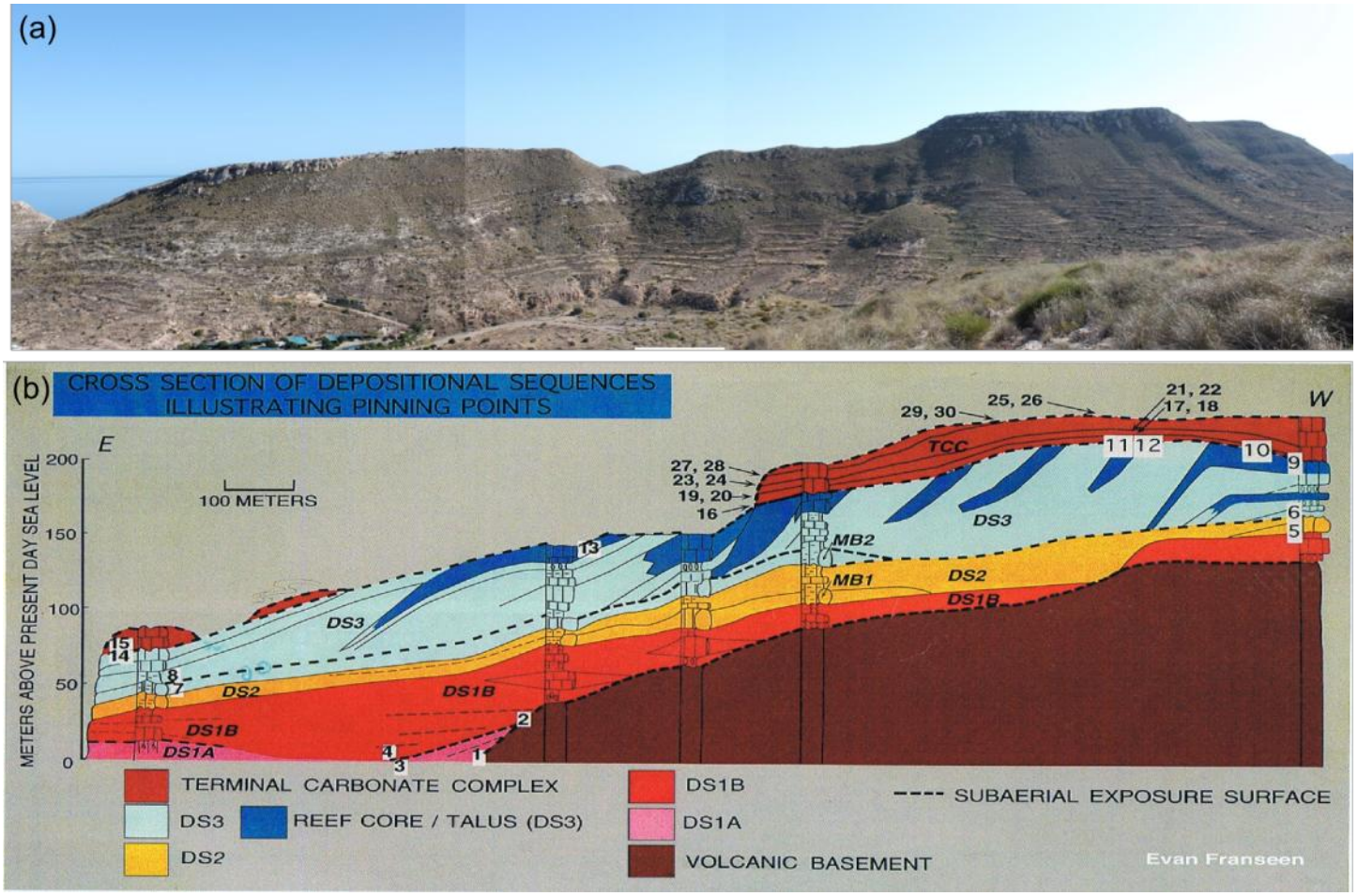


Figure 8. (a) La Molata section as seen from the north. (b) La Molata section as interpreted by Franseen *et al.* (1998). DS1A comprises muddy packstone, DS1B comprises fining upward cycle, DS2 comprises conglomerates and volcanic detritus, DS3 comprises reef cores/talus and TCC is Terminal Carbonate Complex.

References

Braga, J.C., Baena, J., Calaforra, J.M., Coves, J.V., Dabrio, C.J., Feixas, C., Fernández-Soler, J.M., Gómez, J.A., Goy, J.L., Harvey, A.M., Martín, J.M., Martín-Penela, A., Mather, A.E., Stokes, M., Villalobos, M. y Zazo, C. (2003). Geology of the arid zone of Almería (South East Spain). An educational field guide (Editor of English version: M. Villalobos). (Tecnología de la Naturaleza SL-TECNA). Aguas de la Cuenca del Sur, SA (ACUSUR) – Consejería de Medio Ambiente de la Junta de Andalucía, 163 pp.

Esteban, M. and Gerard, J., 2010. Field seminar for seismic interpreters: Carbonate and turbidite sedimentation.

Field Guide, Almeria Basins Field Trip. Repsol Exploración SA (unpublished).

Esteban, M., Braga, J.C., Martín, J. and De Santisteban, C., 1996. Western Mediterranean Reef Complexes. *In*: Franseen, E.K., Esteban, M. and Ward, W.C., Rouchy, J.M. (Eds.), Models for carbonate stratigraphy from Miocene reefs complexes of Mediterranean regions. SEPM. Concepts in Sedimentology and Paleontology Series, vol. 5, 55–72 .

Franseen, E.K., Goldstein, R.H. and Farr, M.R., 1998. Quantitative controls on location and architecture of carbonate depositional sequences: Upper Miocene, Cabo de Gata region, SE Spain. Journal of Sedimentary Research, 68 (2), 283–298

Monie, P., Galindo-Zaldivar, J., Lodeiro, F.G., Goffe, B. and Jabaloy, A., 1991. 40Ar/39Ar geochronology of Alpine tectonism in the Betic Cordilleras (Southern Spain). Journal of the Geological Society, 148 (2), 289–297. doi: 10.1144/gsjgs.148.2.0289

Sanz de Galdeano, C., 2000. Evolution of Iberia during the Cenozoic with special emphasis on the formation of the Betic Cordillera and its relation with the western Mediterranea. Ciência da Terra (CNL), 14, 9–24

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