Exploration Lessons from the Land of 'Magic Realism'*

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Introduction

Imagination, an integrative approach to old-fashioned geology, plus advanced technologies played a leading role in the 2010-13 discovery of the Guama Field in the Plato Region of the Lower Magdalena Basin (LMB) of Colombia. Thinking of a shallower opportunity above a deeper turbiditic prize was just the beginning, though: poor trap image, a sand reservoir with even poorer log signature and challenging reservoir quality, and conditions made Guama the poster child of a nice discovery facing a steep road to commerciality.

Basin Context and Early Exploration

The Plato Depression is home to the first sizable discoveries in the LMB (Figure 1). Back in 1942 and 1964, the El Difícil and Cicuco fields (Figure 2) had been found in Miocene carbonates sitting on uplifted basement blocks that outlined the depocenter below the cattle- and rice–rich region not far from Aracataca, birthplace of Colombia's well-known writer, the late Gabriel García Márquez, and the inspiration for his beautiful "magic realism" literary style.

A first glance of the thick and shaly Miocene section that fills entirely the Plato Depression (Figure 2) was obtained by well Costa Rica-1. This well had been proposed by Imperial Oil's regional geologist K.F. Dallmus in a 1943 letter to O.C. Wheeler, ostensibly looking at a southern analog to El Dificil, discovered by Shell the year before. Costa Rica-1, finished in December of 1946, drilled through more than 10,000 feet of massive Miocene shales, encountering almost no sands.

New seismic readings prompted renewed interest in the deep Plato, where explorers interpreted turbiditic correlatives of the oil-rich carbonates and sands. Thus, wells Guamito-1 and Ligia-1 (Figures 2 and 3) were drilled in 1975 and 1980 by Chevron and Ecopetrol, finding condensate-filled sands regrettably unable to sustain commercial flow.

Fast forward to 2009: Pacific Stratus, a company that in 2008 had signed the Guama E&P Contract with Colombia's Agencia Nacional de Hidrocarburos (ANH) with a view at the deeper (greater than 12,000 feet) "turbidite" play, was preparing to drill the first commitment well for one of several deep prospects defined with recently acquired 2-D seismic data. Concerns over the deep test, however, started growing after Petrolifera's La Pinta-1 well (Figure 2), a twin to Guamito-1, found that the turbiditic sands might not be as good as expected. Further uncertainty over reservoir quality added little attractiveness to a well that would drill through hefty thicknesses of Porquero Formation marine shales, notorious in the region for their ability to complicate drilling operations and junk exploration wells.

Change of Paradigm

With this concern in mind, in 2010 the operator carried out a first seismic inversion to reduce the uncertainty of reservoir presence in the new prospects. This first inversion showed a spectacular pattern of basin floor lobes at target level extending across the prospects – but also showed that the sands that proved to be poor in the Ligia-1 and Guamito-1 wells "shaled-out" towards the prospects. This piece of evidence was definitive in slashing the proposed deep test.

Explorers then began looking instead at gas chimney-like features that had been noticed on older data near the prospective area. These suggested that some gas might indeed be present at shallower (and cheaper!) depths. If only there were sands. ...

A 3-D survey was run in early 2010 in lieu of the first commitment well, something that improved the exploration outlook of the block. The new data showed that the vertical features now looked more like shale diapirs. This new data also showed amplitude anomalies at depths of less than 7000 feet that faded-out well before reaching the shale diapir flanks; AVO analysis indicated them to be gas-prone.

Discovery and General Geology

With a new well commitment and not much time to spare, well Pedernalito- 1X spudded in September 2010. The name of the well, itself a blink at the historic Pedernales diapir play of Eastern Venezuela, became premonitory: gas condensate was short-tested from just a few feet of interpreted pay in laminar sands scattered sparsely and irregularly over the more than 1700 feet of Porquero massive marine shales, albeit at a rather unimpressive flow. This prospective succession, defined between well defined unconformities, was in turn buried under a shale-prone overburden of more marine shales, also crossed by unconformities. It reached almost to the surface and was capped by thin Recent alluvium. Mineralogical analyses indicated that the sands, fairly porous but laminar and scattered in irregular multi-laminae cycles, were rich in clays that strongly affected reservoir permeability and log response. The shales, in addition, were proven to be quartz-rich, which in turn exacerbated an already poor log contrast.

If only the trap were discernible on seismic and the pay showed-up on logs, and only if the wells flowed better … why had it to be that way?

To address so many issues, "good old" geology helped jump-start a workable model (Figure 4): reconnaissance bio by the late Herman Duque-Caro and high-definition biostratigraphy by María Bolívar helped interpreters assign early, middle and late Miocene ages within the complex unconformable architecture of the whole Porquero section. This revealed the equally complex tectonic evolution of the basin as well as a deep marine environment for the prospective Porquero. Meanwhile, fine sedimentological work associated it with a deep-basin-floor environment that formed just north of the early/mid-Miocene Magdalena River Delta (Figure 4). The reservoir sands represent overbank and submarine channel facies. In this context, the structure dips gently to the northwest, while locally the beds are up-folded by PSDM-defined shale diapirs, of which two have been mapped in the area. The diapirs are cut off by the recent Magdalena River alluvium and have no surface expression; so they are considered inactive.

Technology Isn't Everything – But It Helps A Lot

Absent a sufficiently accurate seismic image, the project kept relying on seismic attributes analyses: the second inversion was run after Pedernalito-1X, and this time elastic attributes, including Poisson ratio, were used to locate Cotorra-1X (2011); a third inversion after Cotorra-1X helped locate Manamo-1X (2012) and Capure- 1X (2013), after which a fourth elastic inversion was conducted.

In all, four successful wells, total depth at around 7000 feet, were located entirely on seismic attributes as confidence grew in the inversion model as more control (data) and consistent results were obtained from different workflows run with identical datasets by two different contractors.

On the petrophysical side, pay sands were still very much invisible to conventional log suites. Besides, well performance in short tests suggested that the initial Simandoux evaluations were underestimating the gas pay in all wells, a notion confirmed later by the extended tests. Thus, during the project a workflow evolved gradually in which the final pay discrimination is based on elastic rock properties, magnetic resonance, gamma spectrometry, and well-site mass spectrometry, among other indicators.

Seismic Petroleum System

All four wells of the 2010-13 campaign short-tested gas condensate, and the last one, Capure-1X, also flowed some light oil. Moreover, dry and rich gas observed from almost surface down to total depth suggested that the source column had to be thicker and shallower than the known basin-wide source, Oligo-Miocene in age, older and deeper than the Miocene of the Guama Field.

For this reason, and with exploratory implications in mind, geochemical analyses were commissioned, and the results were rather surprising: biomarkers showed the rich gas to be a 70/30-percent mixture of biogenic methane and thermogenic condensate. Besides, the mandatory rock/fluid correlation confirmed the logically expected relation between produced hydrocarbons and the surrounding Porquero shales. These deep-marine shales, as Van Krevelen graphs reflect, are rich in terrigenous matter and sourced both condensates and light oils that originated in a very early generation window, where vitrinite reflectance in the Guama reservoirs would not exceed 0.5 percent.

With all this in mind, it seems that a description for the Porquero petroleum system, advanced by the multi-disciplinary team (Figure 5) and which is functioning in the Guama Field, requires one single shale source scattered along a very long column, generation of bacterial gas and thermogenic products and in-situ and short distance charge to laminar sands, dispersed over an equally thick section.

Wrapping It Up

In a challenging price environment, immediate development may or may not proceed, but the lessons that the Guama case offers are all out for the taking.

First, Guama is good case of exploration that started with a play in mind – deep and expensive in this case – that evolved with flexible geological thinking and timely use of technology to a shallower, cheaper exploratory concept.

Second, as an exploration project, Guama incorporated reservoir management aspects, including critical data acquisition, such as geomechanical and mineralogical parameters, in order to anticipate information required for the field development plans.

Finally, what a curiosity that such a complex and bizarre petroleum system, so challenging to coming up with models, had to be found in the very land of magic realism!

Author

Juan Francisco Arminio (Figure 6) graduated with a degree in geological engineering from Universidad de Oriente in Venezuela and holds a master's degree in basin evolution and dynamics from Royal Holloway, University of London. He developed his career with PDVSA in production, exploration, and new business development, moving afterward to Colombia as exploration manager for Pacific Stratus, later Pacific Rubiales Energy. Currently with New Stratus Energy, he is also a post-graduate professor at Universidad Simón Bolívar, Venezuela.

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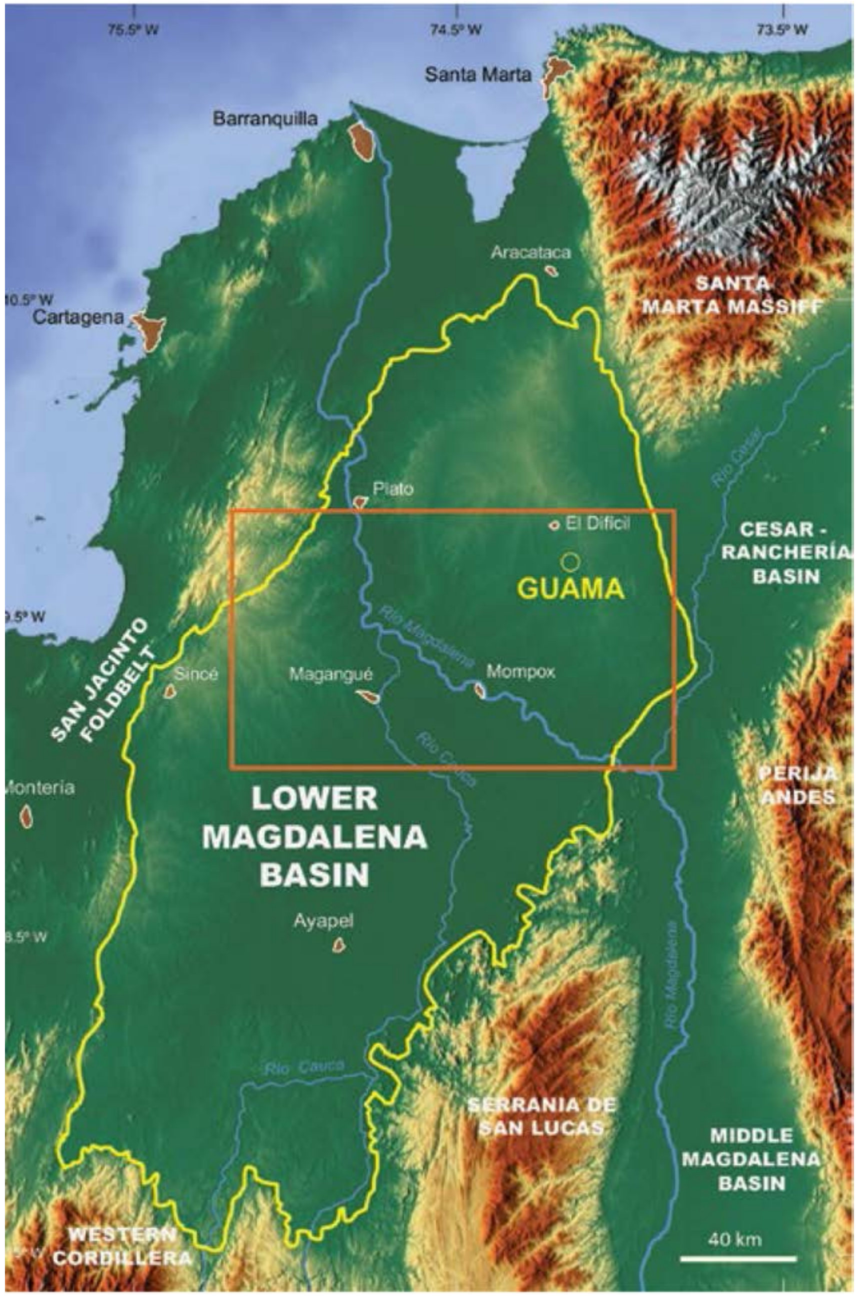

Figure 1. Index map showing location of Lower Magdalena Basin and Guama Field in Plato Region, Colombia.

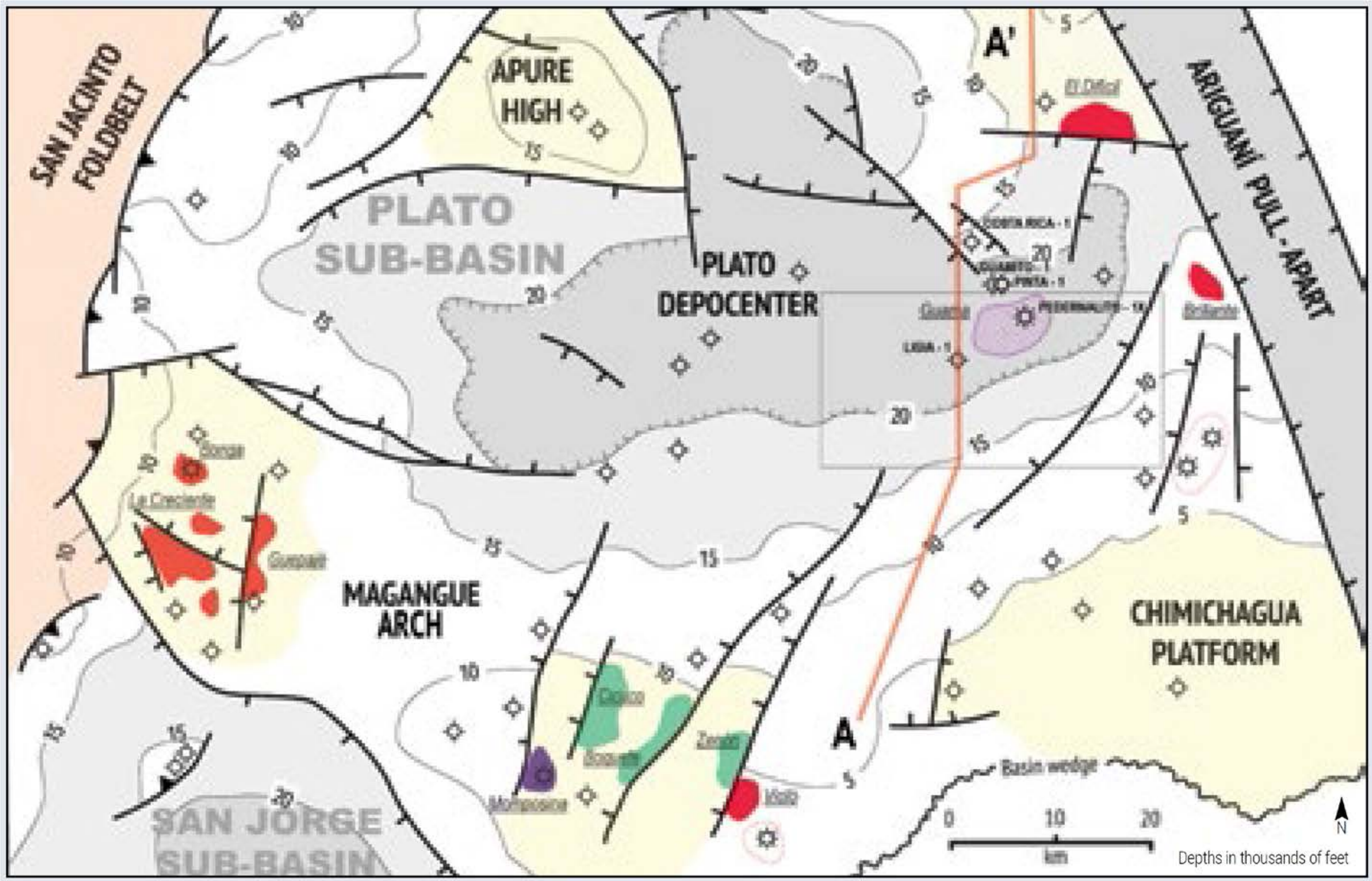

Figure 2. Generalized structural map of Plato "Depression" and environs, with the sizable El Dificil and Cicuco fields, discovered decades before Guama Field, the subject of this article.

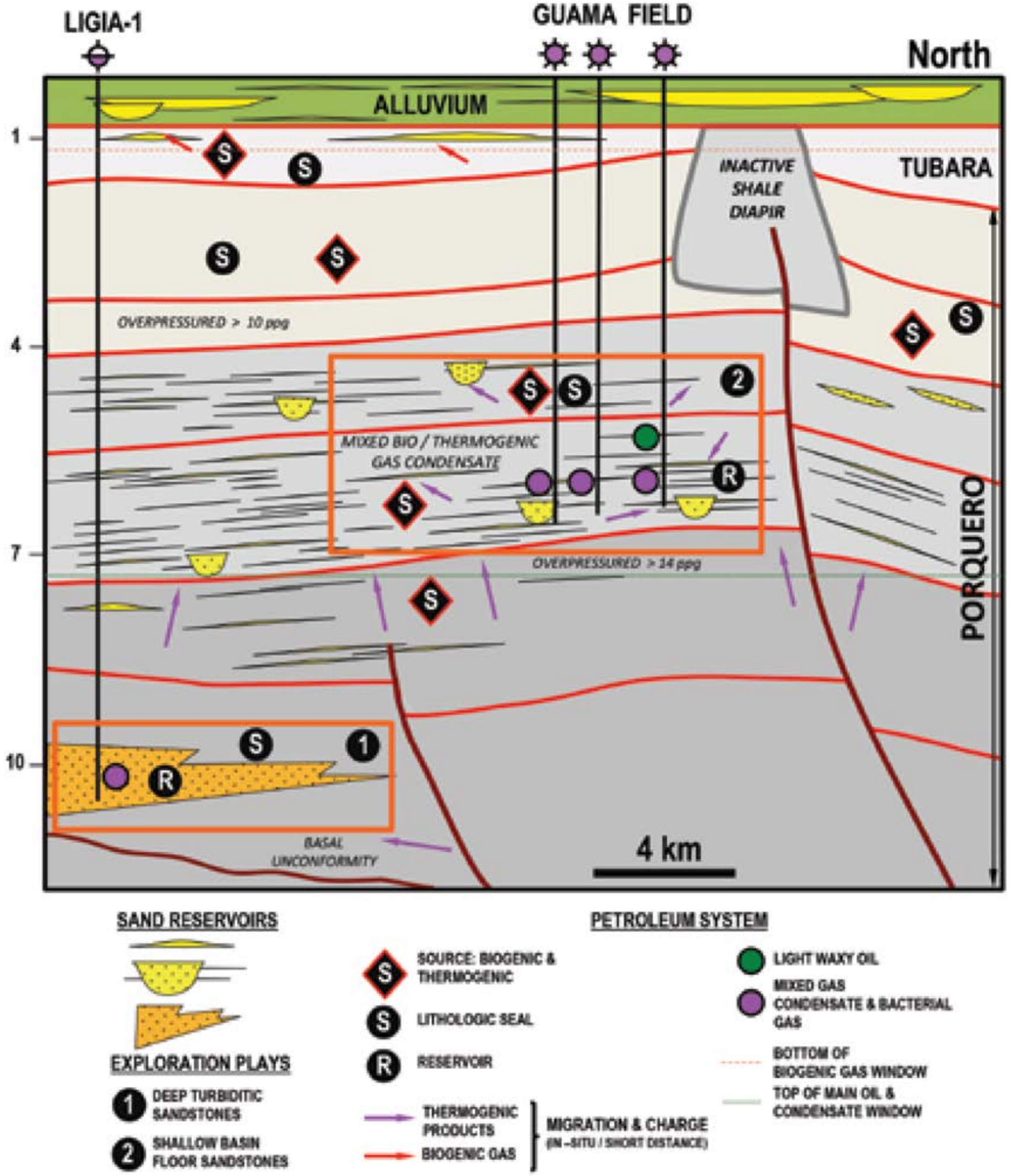

Figure 3. Cross-section through Guama field, showing the positions of source, reservoir, and seal.

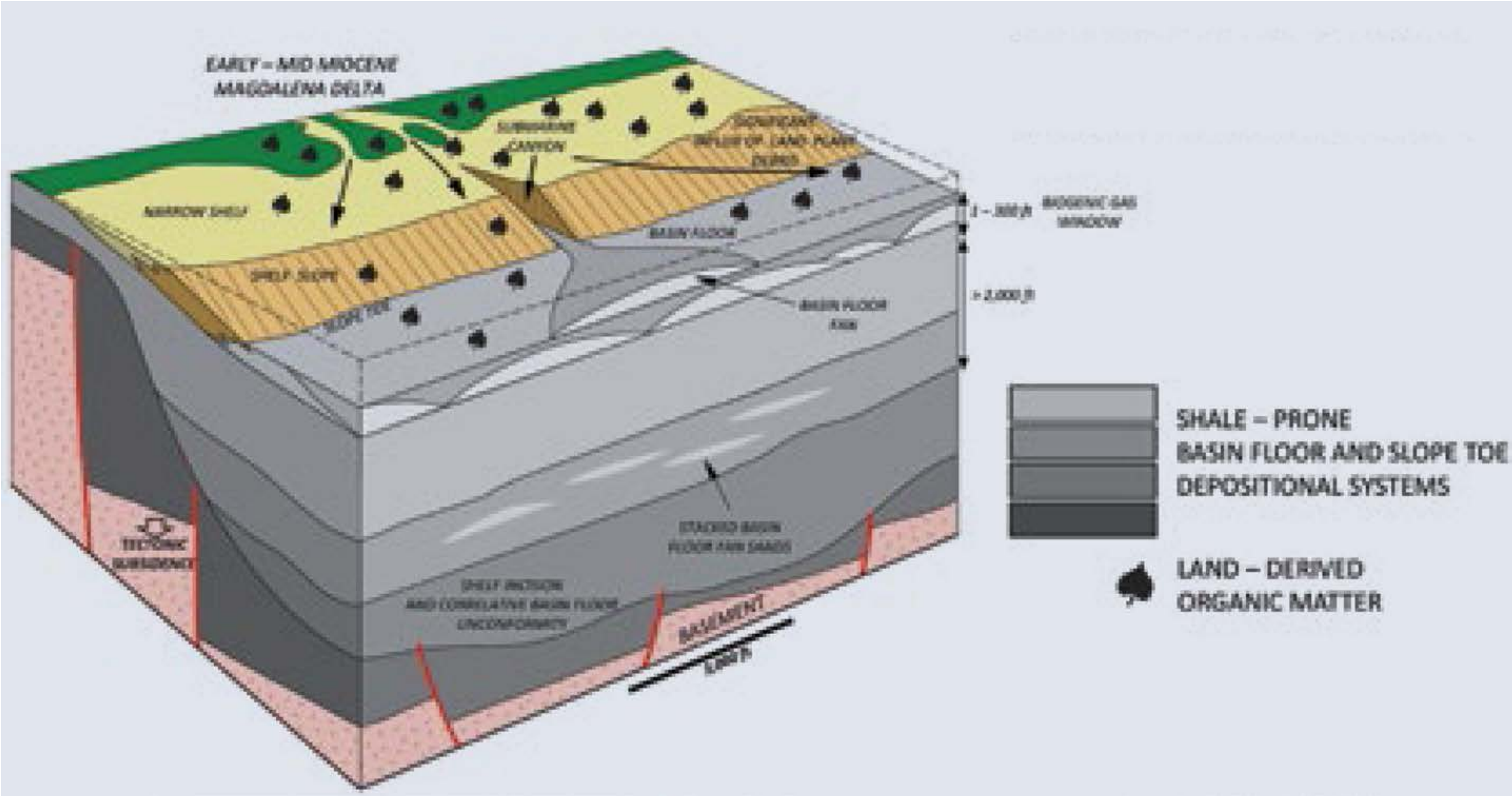

Figure 4. Deep-marine conceptual model of Porquero sand facies, Guama Field.

Figure 5. Persons instrumental in discovery and development of Guama Field. Standing, right to left: Vicmar Azuaje, Mario Di Luca and Trino Salinas (seismic interpretation and modeling), Jose G. Betancourt and Eduardo García (green poster) both petrophysicists, and Gonzalo López and Juan Vargas, geologists. Sitting: Diana Ruiz, reservoir engineer, and Juan F. Arminio, project manager. Screen: Lino Castillo, reservoir geologist.

Credits to: Jairo Lugo (VP Exploration), Angel Dasilva (exploration geophysicist), Santosh Ghosh (sedimentologist), Suhas Talukdar (organic geochemist), Juan Tavella and Omar Pimentel and their teams (seismic modeling), Rudyard Vega (reservoir engineer), Ivan Leyva and Franklin Yoris (geologists) and Gabriel Alvarez (geophysicist).

Figure 6. Juan Francisco Arminio, author.