Big Data - Planning for Success in Ultra-Deepwater Colombia Basin

Andrew L. Mehlhop[1] and Brian R. Frost[2]

[1]Anadarko Petroleum Corporation (andrew.mehlhop@anadarko.com)
[2]Anadarko Petroleum Corporation (brian.frost@anadarko.com)

ABSTRACT

Between the summer of 2015 and July 2016 Anadarko Petroleum Corporation acquired over 100 TB of 3D seismic data in the Western Caribbean Sea. The Esmeralda survey covers almost 30,000 km^2 in water depths ranging from 1,700 to 4,000m. State-of-the-art seismic boats were used towing 12 hydrophone cables with a spread 8.1 km long and 1.2 km wide. Shot point spacing was 25m and record length was 15 seconds at a 2msec sample rate which made it possible to image the Moho.

The data were fast track pre-stack time migrated onboard the seismic vessels and delivered "ready to interpret" as swaths of the acquisition were completed. Delivery of the final fast-track data cube occurred in October 2016 and the final pre-stack depth migration will arrive in October 2018.

Planning for success in Colombia began in 2006 when a frontier basin screening exercise identified the offshore Caribbean as an underexplored area with geologic characteristics potentially favorable for large deepwater petroleum accumulations. The Magdalena Fan has a thick accumulation of Tertiary clastics that could provide reservoirs, seals, and overburden to mature source rock. Deepwater DSDP cores drilled on the flank of the fan contained a thin but very anomalous interval of mid Cretaceous organic material of similar age and facies to the prolific La Luna source rock that could provide charge if they thicken beneath the fan.

Previous onshore and shelf drilling discovered a five TCF gas field at the coastline and a few sub-commercial gas and oil shows. Could this be the smoking gun for an untested deepwater petroleum system? Anadarko spent the next several years acquiring data, confirming the knowns vs assumed about the petroleum system of the Magdalena Delta, and considering what was possible in the deepwater Fan. Shelf and upper slope seismic data was available from unsuccessful exploration programs in the 70's through 1990's, but seismic data over the toe of slope and basin floor had to wait until industry began pushing back the limits of deepwater exploration in the Gulf of Mexico (GOM) in the 2000's.

Beginning in 2004, the Colombia petroleum regulatory agency (ANH) granted Technical Evaluation Agreements (TEA) over large areas for a limited period to conduct regional exploration for choosing prospective areas to negotiate E&P contracts exclusively. This encouraged investment in offshore exploration and resulted in the acquisition of new regional long offset, long record length 2D data from the shelf to the toe of slope. The data showed interesting structures at the end of lines with uncalibrated direct hydrocarbon indicators (DHIs) but in water depths exceeding 3600m. The only line acquired over the basin floor of the Magdalena fan showed large bumps with apparent stacked flatspots in 3950m water depth but industry was just not ready at this time to chase petroleum at these water depths in a frontier basin.

Meanwhile new exploration well and production facility water depth records were being set internationally and in the Gulf of Mexico (GOM). Anadarko was late to the game but caught up quickly. Its offshore experience in the 80's and 90's was on the shelf and it was not until 2000 that the company moved into deepwater in a big way with the GOM discovery of the Marco Polo field in 1310m water depth which produced its first oil using a tension leg platform (TLP) in 2004.

This success was quickly followed up by Anadarko's 2004 discovery of the Cheyenne field in 2740m water depth that produced its first gas in 2007 using a moored gas facility called Independence Hub. With Independence Hub, Anadarko pushed the boundary for technological and operational achievement and created industry records and business models for future deepwater exploration and production. The $2 billion development produced gas reserves from 10 anchor fields and at peak production, processed 1 Bcf of natural gas per day.

Further deepwater discoveries in Ghana (2007) and Mozambique (2010) pushed Anadarko into the major league of deepwater companies at about the same time as the ANH in Colombia offered its first ultra deepwater TEA's in 2010. Anadarko took the plunge in 2012 and acquired 8MM acres in 4 exploration blocks and 2 TEA's offshore Colombia.

Anadarko's exploration philosophy is to plan for success. The existing 2D seismic in the deepwater Fuerte area of the Magdalena Fan showed the potential for combination structural and stratigraphic traps and sufficient uncalibrated DHIs were present to define a sizeable petroleum system fairway. Prospect definition required 3D and Anadarko shot the 5200 km^2 Purple Angel survey, at the time it was the biggest proprietary survey acquired in the company's history. Anadarko also picked up a TEA in the Colombia Basin area of the Magdalena Fan where the DHIs in 3600m water depth were located. There was not enough seismic to define a play fairway across the deepwater Magdalena Fan so a regional 2D program was acquired.

The results from these work programs were spectacular. The Purple Angel 3D defined large prospects with fit to structure DHIs in the Fuerte area of the Magdalena Fan and the Colombia Basin 2D program identified combination structural stratigraphic leads with good class 2 and class 3 AVO anomalies right in the heart of the Magdalena Fan. The results came in at about the same time the ANH announced a bid round for 2014 and the ANH data package included a new regional ultra deepwater 2D survey over the Colombia Basin. The 50X80 km grid identified the missing play elements for the basin and defined what could potentially be a world-class petroleum system fairway with supergiant potential. Based on Anadarko's favorable results from the Purple Angel survey, the company acquired an additional 8MM acres in 3 TEA's in the Colombia Basin and committed to shoot the 30,000 km^2 Esmeralda 3D Survey.

The drilling campaign in the deepwater Fuerte area commenced in 2015 with a gas discovery on the Kronos prospect and culminated with a 2017 IHS top ten discovery at the Gorgon prospect that is the largest gas field discovered in Colombia in 28 years. The well information provided valuable fluid and rock property data to calibrate the seismic response of hydrocarbons in the deepwater Magdalena Fan.

The Esmeralda fast track cube defines over 40 large prospects with thick intervals of AVO anomalies, fit to structure amplitude anomalies, and flatspots. The results of recent seabed piston coring in the Colombia Basin support the hypothesis that the DHIs seen in the Esmeralda 3D indicate a large liquids-rich petroleum system is present in this separate sub-basin in the heart of the Magdalena Fan. Simple deterministic and

probabilistic calculations based on the numerous prospects revealed from the 3D data suggest that there could be a multi-billion barrel resource located in the heart of the Magdalena Fan in ultra-deepwater. This puts the potential of the deepwater Colombia Basin play on par with the

known resource potential of East Venezuela and make it a candidate to be the next world-class “Super Basin”. The first exploration well in the Esmeralda 3D area is planned to spud 2019.