Introduction

Argentina held its first offshore oil and gas licensing round during March 2019; 38 blocks were offered, 18 of which were licensed. Of these, 14 are located in the far south of the Atlantic margin, 10 in the Malvinas Basin, 3 in the Austral Basin, and 1 block that straddles the boundary between the two (Figure 1). Of all the basins where acreage was provided, only the Austral Basin currently contains commercial hydrocarbon accumulations. The Austral Basin, including its extension into Chile where it is known as the Magallanes Basin, has cumulatively discovered volumes of almost five billion BOE (Schiuma, 2018). The majority of production has occurred onshore, but several significant fields are wholly or partially offshore, including the Ara-Cañadón Alfa, Carina, Argo, and Hidra fields (Figure 1). The Malvinas Basin is linked to the Austral Basin by a shared tectonic development; as a result, the stratigraphic fill is similar in both instances. The two basins are separated by a basement swell called the Rio Chico High or Dungeness Arch, which is a fundamental feature dictating the location of traps in the Austral Basin. Despite these similarities, the Malvinas Basin remains largely unexplored.

![Figure 1 Location of oil and gas fields in the Magallanes Basin and direct hydrocarbon indicators in the Malvinas Basin.](image)

However, there are many indications that the Malvinas Basin contains hydrocarbons. Currently, 19 wells have been drilled, 5 of which contained evidence of hydrocarbons (Galeazzi, 1998) in addition to the presence of direct hydrocarbon indicators in seismic (Baristeas et al., 2012). Well penetrations confirm the extension of the main petroleum system elements from the Austral into the Malvinas Basin, including the primary reservoir and source rock—Springhill and Lower Inoceramus formations, respectively (Figure 2b). This study draws on available seismic, well, and petroleum systems data to highlight the potential risks to exploration success in the Malvinas Basin. To understand them requires placing the geological evolution of the basin in context.

Geological Evolution

The stratigraphic fill of the Austral and Malvinas basins can be divided into three broad phases: syn-rift, passive subsidence, and foreland (Figure 2a). Rifting began in the Middle to Late Jurassic during the early stages of the disaggregation of West Gondwana that culminated in the opening of the South Atlantic. Rifting was accompanied by the extrusion of voluminous volcanic rocks assigned to the Chon Aike Large Igneous Province (LIP) (Pankhurst et al., 1998). In the Austral and Malvinas basins, this is recorded by the Tobifera Formation. There is also evidence of sedimentary rocks with elevated organic carbon content in the syn-rift successions of the Austral Basin—the Lemaitre Formation of Cagnolatti et al. (1996).

Continued extension and lithospheric thinning culminated in the creation of a marginal seaway in a back-arc setting, commonly referred to as the Rocos Verdes Basin. The Rocos Verdes Basin was a precursor to the Austral Basin, and the remnants of the basin axis are currently preserved by the Rocos
Verdes ophiolite complexes exposed in the Fuegian Andes to the west (Stern and de Wit, 2003). In the Malvinas Basin, lithospheric thinning did not result in the creation of mafic crust, but a similar stratigraphic response is recorded. In both cases, syn-rift stratigraphy is truncated by an angular unconformity and draped by transgressive deposits that mark the initiation of passive subsidence. The basal package is comprised of sandstones known as the Springhill Formation, which is markedly diachronous from south to north and west to east. The Springhill Formation in the Austral Basin, where it is best studied, comprises a lower continental member that yields to a transitional and, finally, a marine member. Each member demonstrates a characteristic wireline log signature which is important for describing reservoir properties within the Springhill Formation (Sotelo et al., 2005). The transgression is capped by an Aptian maximum flooding event that resulted in the deposition of the primary source rock and seal in both basins. The shales deposited during this time are variably referred to as the Lower Inoceramus or Palermo Aike formations and are broadly coincident with Oceanic Anoxic Event 1a. This stratigraphic package contains the most important petroleum system elements in the Austral Basin and the primary exploration targets in the Malvinas Basin.

The remainder of the passive subsidence phase is marked by overall regression because the rate of subsidence slowed and was progressively outpaced by sediment accumulation rates. In the Austral Basin, progradation occurred from the north and east and proceeded basinward through time (Biddle, 1986). In the Malvinas Basin, progradation was less marked and occurred principally from north to south (Galeazzi, 1998).

Closure of the Rocas Verdes Basin began in the middle Cretaceous and was complete by the Late Cretaceous (Stern and de Wit, 2003). This process is observed on seismic data by progressive onlap of the eastern margin of the Dungeness Arch and was responsible for the creation of the Austral foreland basin observed currently. The Malvinas Basin was largely unaffected during this process.

At the latitude of the Austral and Malvinas basins, the Fuegian Andes forms an orocline that is strongly influenced by the opening of the Drake Passage and insertion of the crust underlying the Scotian Sea between Antarctica and South America (Eagles, 2010). This process occurs diachronously from west to east and resulted in the inversion of the southern portion of the Malvinas Basin starting in the Paleogene and culminating through the middle Eocene-Oligocene (Galeazzi, 1998). The Malvinas Basin became a foredeep at this time and is characterised by a wedge of clastic sediment that prograded from the north and west to fill the newly created accommodation space (Galeazzi, 1998).

**Figure 2** a) Schematic cross-section showing the tectonostratigraphic sequences in the Malvinas Basin; b) schematic cross-section showing the primary plays of the Malvinas Basin (modified from a seismic section in Lovecchio et al., 2019).
Comments on the Hydrocarbon Prospectivity of the Malvinas Basin

The tectonic development and resultant stratigraphic infill of the basins previously discussed caused a relatively unstructured post-rift succession. In addition, the fact that the source rock in the basin directly overlies the reservoir requires downward migration, juxtaposition by fault offset, or shallowing of the reservoir onto subsurface highs to charge traps (Figure 2b). In the Austral Basin, charge takes place from the foredeep in the west into shallow reservoirs on the flank of the Dungeness Arch to the east. To date, wells drilled on the eastern flank of the Dungeness Arch in the western part of the Malvinas Basin have been unsuccessful, with evidence that many of the traps are underfilled.

However, abundant hydrocarbon leakage indicators in the foredeep area indicate the presence of a thermogenic source rock that is currently mature and actively expulsing hydrocarbons (Baristeas, 2012). The discrepancy between these two details could be related to the fact that much of the produced hydrocarbons are trapped closer to the kitchen area. As such, it is important to determine the position of traps in proximity to the kitchen area. To this end, the hypothesised source rock extent was defined from paleofacies maps for the vital source rock intervals. These were used in conjunction with a regional depth framework created for the Malvinas Basin from publicly available seismic data. The depth to maturity was defined using current geothermal gradients but modified using heat flow data after Sache et al. (2016). A buffer was applied to the area interpreted to be underlain by mature source rock using standard geoprocessing techniques in ArcGIS. Three distances were chosen—60, 120, and 180 km—based on a comparison with the Austral Basin. They indicate that the northernmost of the provided acreage might not be within the fairway for hydrocarbon migration, and, they might be dry or underfilled if traps do exist (Figure 3).

![Figure 3 Map showing the kitchen and maximum extent of the migration pathway for both the Tobifera and Lower Inoceramus source rocks in the Austral and Malvinas basins.](https://example.com/figure3.png)

Additional consideration was given to the potential for syn-rift plays in the Malvinas Basin. Minor production comes from the syn-rift Tobifera Formation in the Austral Basin, and there are indications that it could contain both source rock and reservoir in the Malvinas Basin. The benefit of the syn-rift stratigraphic package is that, unlike the post-rift, it is well structured by extensional faults that create trapping mechanisms (Figure 2). The strategy previously outlined was conducted for the syn-rift, but with the migration, distance was limited to 30 km (Baristeas et al., 2012). Common chance segment maps were created for the interpreted migration fairway for the syn-rift play. Again, they indicate that the most prospective acreage in the Malvinas Basin could be located in the southernmost part of the basin. Note that a good correlation exists between this assertion and the location of hydrocarbon leakage indicators published by Baristeas et al. (2012) (Figure 3).
Conclusion

There is plentiful evidence to suggest that the Malvinas Basin is the most prospective of the underexplored basins in the Argentine South Atlantic, a conclusion reflected in the choice of acreage acquired by companies during the previous licensing round. However, exploration in the Malvinas Basin is not free of risk. Analyses conducted by the service company indicate that chief among these are likely to be the presence of structural or stratigraphic traps within the migration fairway and whether traps will have sufficient closures to contain economic quantities of hydrocarbons. The blocks licensed in the northernmost part of the Malvinas Basin might not fall within the fairway for hydrocarbon migration away from the kitchen area in the south. The blocks in the southern part of the study area are adjudged to be more prospective and contain the possibility of a syn-rift play analogous to the productive Tobifera Formation play in the adjacent Austral Basin.

References


