ADAPTING OIL AND GAS GEOSCIENCE BEST PRACTICES FOR PLANETARY EXPLORATION AND PROSPECTING. D. T. Butler[1] , M. Miller[2], and M.C. Amrouche[3], [1]SLB, 10001 Richmond Ave, Houston, TX 77042 (dbutler4@slb.com), [2]SLB, 10001 Richmond Ave, Houston, TX 77042 (mmiller9@slb.com), [3]SLB, Algiers, Algeria (AMohamed116@slb.com).

Introduction: As oil and gas exploration has evolved, the industry has been forced to develop new techniques and practices for modeling and prospect evaluation. Even with 100+ years of advances in exploration technology, the global success rate for offshore exploration wells ranges from 25 to 40% [1]. The unforgiving nature of oil and gas exploration means data best practices are extremely important. Because planetary science and extraterrestrial prospecting are in their infancy, it is imperative to not reinvent the wheel but learn from the oil and gas industry. In this paper, the authors present examples from the oil and gas industry and introduce their merit in planetary geoscience applications.

Oil and Gas Exploration Workflow Examples: An adequate understanding of the subsurface is critical aspect for oil and gas exploration. Integration of different studies from geophysics, geology, reservoir modeling, and dynamic flow simulation are required to provide the necessary insights and data for decision making through the exploration and production lifecycle. These practices include:

- Visualization and integration of multiple data types in one place
- Unseal data when possible, to build models, and incorporate new data frequently
- Treat data as an asset
- Look to the future when making decisions.

The two terrestrial case studies the authors examine are from frontier basins where geoscience data, and more importantly, drilling data availability are limited. The data serve as potential analogues for future extraterrestrial prospecting.

Campeche Bay Carbonate Mapping. The geology of the Bay of Campeche in the southern Gulf of Mexico is particularly complex and features mixed clastic and evaporites along with complex salt tectonic properties. The same geologic processes that make this basin an excellent candidate for hydrocarbon reservoirs prove to be a challenge to model through seismic imaging alone. As such, a holistic, multiphysics approach was used to resolve model uncertainty and estimate spatially variant carbonate thickness and pore pressure for the 3D earth model. This approach takes advantage of software that simultaneously hosts and visualizes 3D seismic, well data, and performs 3D gravity inversions. Incorporating all these data types proved to be highly successful. Perez et al. [2] also noted that this model can be refined further. As such, the data are saved as an asset for future work.

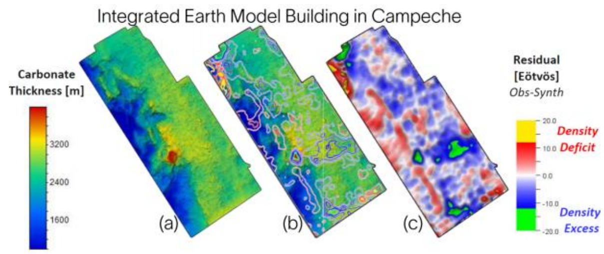

Figure 1 Showing the spatially variable carbonate thickness found through the integrated model approach undertaken by Perez et al. [2]. (a) Example of carbonate thickness map, (b) carbonate thickness map with FVD gravity residual contours (every 4 Eötvös) overlaid (c) First Vertical Derivative (FVD) gravity residual map.

Brazil 2D Reimaging: Originally acquired in 1999, Brazil's Equatorial Margin 2D encompasses four seismic acquisitions, three geologic basins, and 312 2D seismic lines. These 2D seismic lines extend as long as 700 km. At the time of their acquisition, the only way to process these lines was on a line-by-line basis. Any basin or regional study was reliant on individual processors. Advances in both hardware and software have allowed for these data to be reprocessed in one, single, 3D model encompassing all three depositional basins. Additionally, this reprocessing has incorporated 60+ wells to better constrain and update the model. These efforts have yielded impressive results; i.e., a 500,000 km^2 interpolated 3D model of the geology, improved seismic/well ties, and decreased mis-ties from intersecting 2D lines. By incorporating a holistic approach using all available data, the resulting model aims to mitigate risk and uncertainty. Additionally, because the 3D model was saved in a standardized format, future data acquisition can build upon this work by taking advantage of the 3D model created from these 2D lines. Finally, all this reprocessed data (not just the 3D model) were saved as an asset for future processing.

Current Planetary Science Studies

Understanding Multiring Basin Structures. The Orientale basin on the Moon is one of the most interesting multiring structures known in our solar system. Studying its subsurface structure can help to provide a better understanding of the genesis mechanism of all the multiring basins in the solar system. Amrouche et al. [3] used existing aerial interpretation studies of the Oriental basin and integrated the studies with 3D subsurface density contrast modelling using gravity measurements acquired by the Japanese lunar orbiter Kaguya (SELENE) (Figure 2).

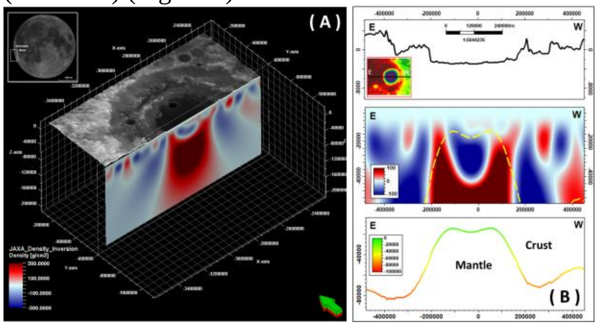

Figure 2- (a) East-west cross section of subsurface density contrast, (b) close-up cross section with surface topography with density contrast and inverted crustal thickness [3]

The estimated subsurface structure correlates well with the suggested circular faults initially interpreted as topographic troughs, which connect the lunar mantle to the surface. In this case study, Amrouche et al. [3] correlated image analysis with 3D gravity inversions within the same software package to better understand the nuanced lunar subsurface. One of the lessons learned from this work was to save and export future E&P software platform projects for additional analysis. Liang et al. [4] applied this method by saving their E&P software platform project for future reprocessing, which in turn, has the potential to continue adding value to the asset.

Ongoing Martian Ice Cap Exploration. The Planetary Science Institute (PSI) has previously processed and delivered SHARAD radar in the SEGY format for multiple Mars regions [5]. Exploration of the Planum Boreum region of the Martian North Pole using 3D SHARAD volumes has revealed distinct geologic facies as well as proposed unconformities [6]. To better understand some of the features and smooth the geologic complexities, the authors of this paper are currently undertaking 3D interpretation of the facies of this region using SHARAD SEGY data volume processed and provided by PSI. Moving forward, we plan to incorporate other planetary data sets into this volume to enhance our understanding and geologic history of the region. Additionally, this work will be preserved to be used in future studies. Figure 3 shows the ongoing work to interpret this region in 3D.

PSI publishing these data in the universal SEGY format provides opportunities for others to add additional value to the data as an asset. By uploading and interpreting these data in the E&P software platform, the platform can be used to readily process other 3D data sets, which opens the door for additional, holistic model building.

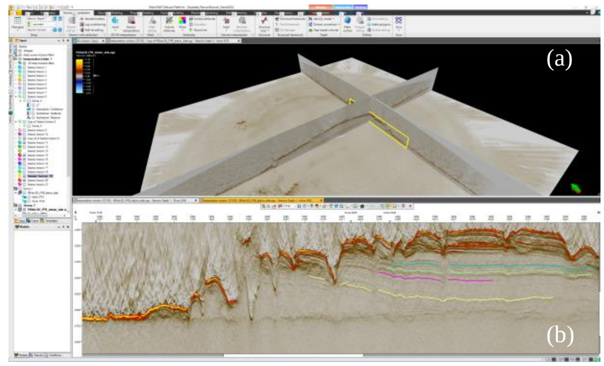

Figure 3 SLB E&P software platform was used to explore the Planum Boreum: (a) 3D window displaying the inline, crossline, and Z slice of the SHARAD SEGY of the Planum Boreum (b) Various geologic facies being interpreted by guided 3D autotracking

Conclusions: Currently, most planetary science software suites are confined to narrowly focused programs, which typically only work with one or two data types, restricting cross-domain collaboration between geoscientists. Additionally, many of these datasets are acquired and processed to resolve a singular question and are not integrated into other modeling use-cases. Using the best practices outlined in the work, these datasets have the potential to keep adding value not just to prospecting, but additional sequences in the space resources value chain. Current and future lunar geoscience data have the potential to be integrated together to build holistic, geoscience models within the same software package. Integrating data together using standardized formats has the potential to open new paradigms for integrated planetary subsurface studies.

References: [1] Rystadt Energy, Petroleum Review (2021). [2] Perez et al. (2021) Integrated earth model building in the shallow water Bay of Campeche in the Gulf of Mexico, *First International Meeting for Applied Geoscience & Energy*. [3] Amrouche M., and Saibi H. (2021) Lunar Orientale Basin subsurface structure estimated from Kaguya (SELENE) orbiter data inversion, *Sixth International Conference on Engineering Geophysics.* [4] Liang F., Amrouche M., Yan, J., and Saibi H. (2024) Detection of subsurface density structures of the Aristarchus plateau by gravity inversion, JGR planets. [5] Putzig, et al. (2018) Three- dimensional radar imaging of structures and craters in the Martian polar caps, *Icarus*, 308:138-147. [6] Nerozzi, et al. (2022) The north polar basal unit of Mars: Amazonian record of the surface process and climate events, *Icarus*, 373:114714.