Energy & Geoscience Institute
AT THE UNIVERSITY OF UTAH

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In Development

Red Sea and Gulf of Suez Basins

Tectonostratigraphic elements from source rocks to traps

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Sponsorship & Contract Information:
Energy & Geoscience Institute (EGI)
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Investment per Sponsor
$74K (USD)

Duration
18 months

EGI Ref# I 01400

Value

- Better understanding of the tectono-sedimentary evolution of the Red Sea and Gulf of Suez basins for petroleum exploration with a focus on key petroleum systems elements from source rocks to traps.
- An ArcGIS quick assessment and easy-to-use tool for analysis of petroleum plays in the region based on an integrative database that can be augmented to the internal databases of the sponsoring companies. This would help to assess data-poor frontier or deeper plays based on regionally correlatable plays.

Key Deliverables

1. An integrative geologic model for the opening of the Red Sea and Gulf of Suez with a focus on the impact of tectonics on synrift depositional facies, and high-resolution, standardized stratigraphic correlation of the region bordered by six different countries (Egypt, Saudi Arabia, Sudan, Yemen, Eritrea, and Djibouti) which use different stratigraphic terminologies.
2. An evaluation of pre-salt (pre-Late-Miocene) and pre-rift (Jurassic-Eocene) sedimentary packages and petroleum plays in the Red Sea basin constrained by paleofacies reconstruction and correlatable source rocks and geochemical data.
3. An examination of geologic factors for the success of giant fields in the central Gulf of Suez sub-basin as an analog for similar possibilities in the Red Sea basin
4. Play fairway mapping of hydrocarbon prospectivity in selected key areas in the Red Sea based on a synthesis of information from wells, seismic, and other data.
5. An atlas of seismic, stratigraphic, and well data for quick reference and use.

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Rationale & Significance

Regional Framework

The Red Sea Basin (RSB) rift (Figure 1) runs for 2,250 km in an NNW–SSE trend between the African and Arabian plates and has a maximum width of 355 km. The sea-floor spreading is about 1.6 cm/year from the spreading center so that divergence between Arabia and Africa is taking place at a rate of about 3.2 cm/yr. RSB is considered to be an active example of early-stage ocean opening and thus offers significant clues to structural and sedimentary evolution from a continental rift to a passive margin drift setting. An interesting feature of RSB rift is that the spreading center, rather than being a "mid-ocean ridge," is actually a trough (>3000 m deep). Closely associated with RSB are the characteristics of petroleum systems (source to entrapment) in such settings, thus offering valuable analogs for other, older rift-drift margins in addition to RSB being a highly prospective young petroleum basin setting.

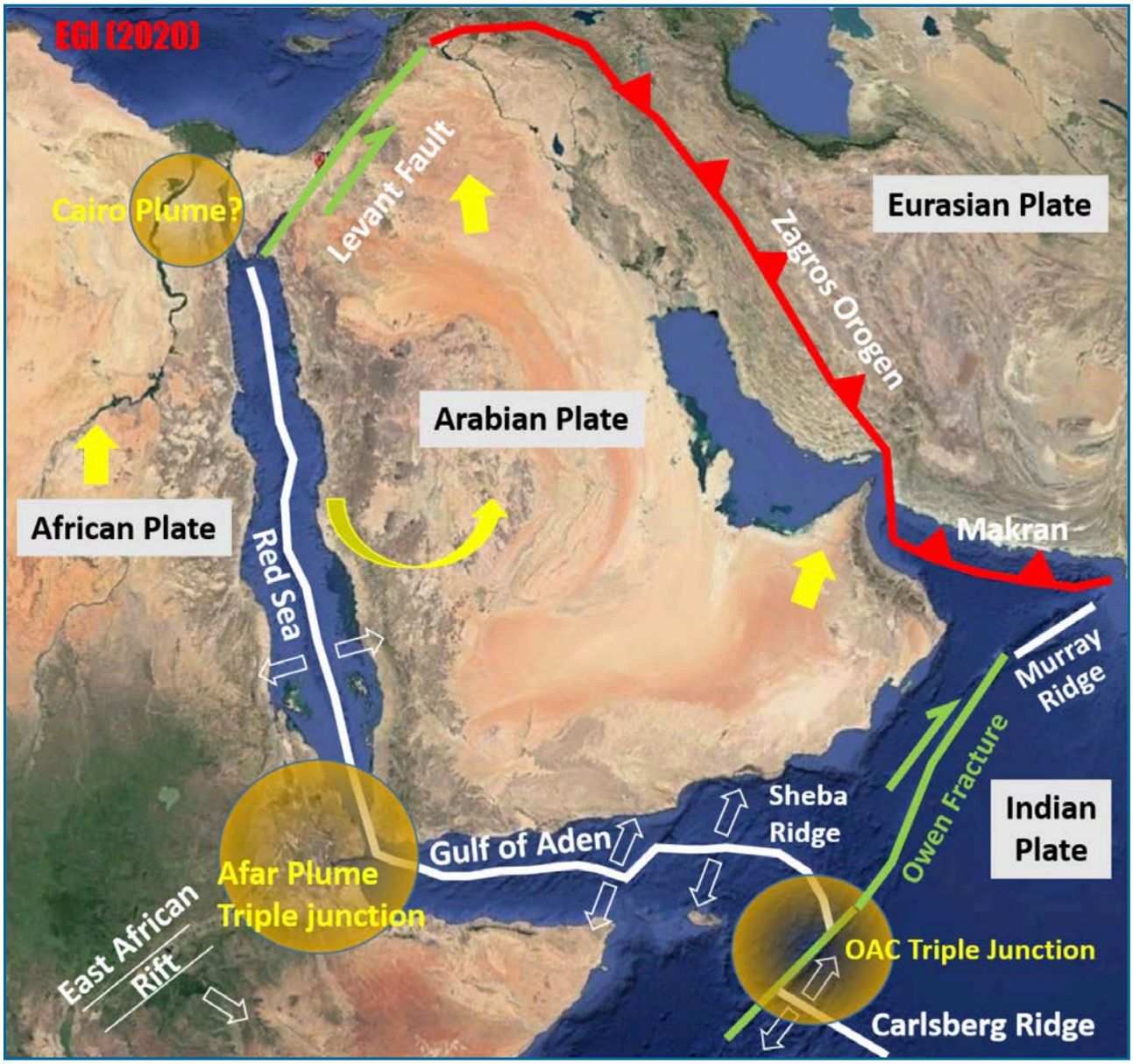


Figure 1. Plate tectonic setting of the Red Sea Basin

There are abundant oil and gas seeps both onshore adjacent to the Red Sea and on islands in the Red Sea, indicating active charge in the subsurface. There is a sporadic history of drillings, both coastal and offshore in RSB, resulting in a number of dry wells or non-commercial shows and some field discoveries (Figure 2). The discovery of Burquan oil field (1971, north Saudi Arabian side) and the Bashayer and Suakin gas fields (1976 Chevron/Texaco offshore Sudan) are the earliest proven concepts of Miocene petroleum systems in RSB. In recent years, there has been a renewed interest in petroleum exploration in RSB both because of its infrastructures (proximity to Europe and offshore transportation) and successes in the Midyan and Jaizan basins (discovered in the 1990s and located respectively in the northern and southern ends of coastal-offshore Saudi Arabia). All these discoveries are proven Miocene petroleum systems while deeper targets remain little explored. Egypt has opened a number of blocks in the Red Sea, where Chevron, Mubadala, and Shell have taken positions (Figure 3).

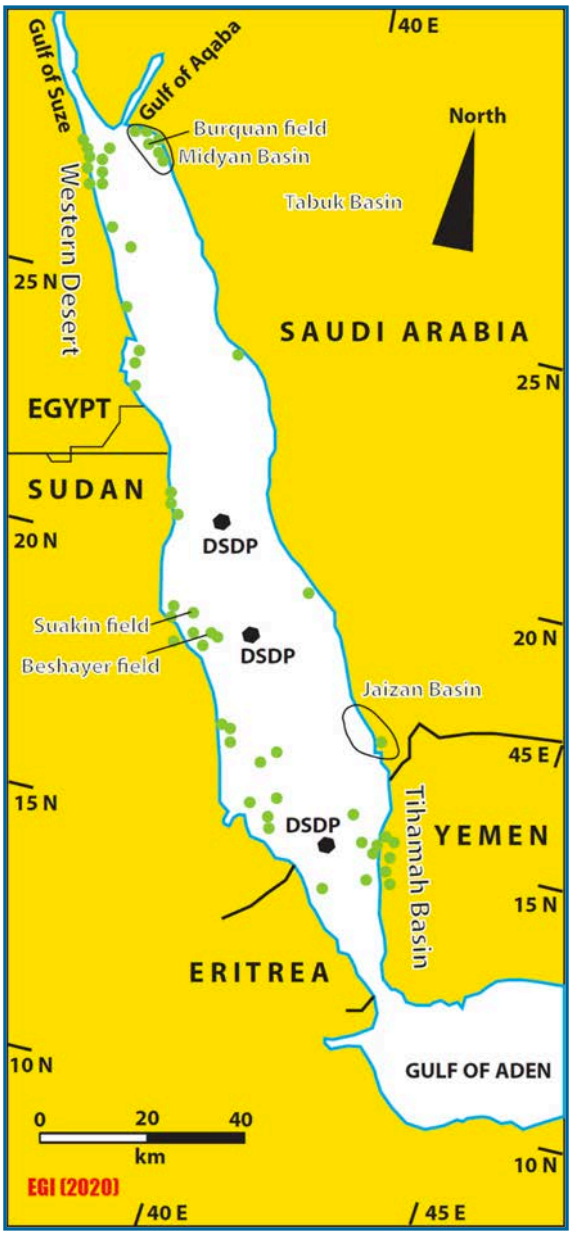
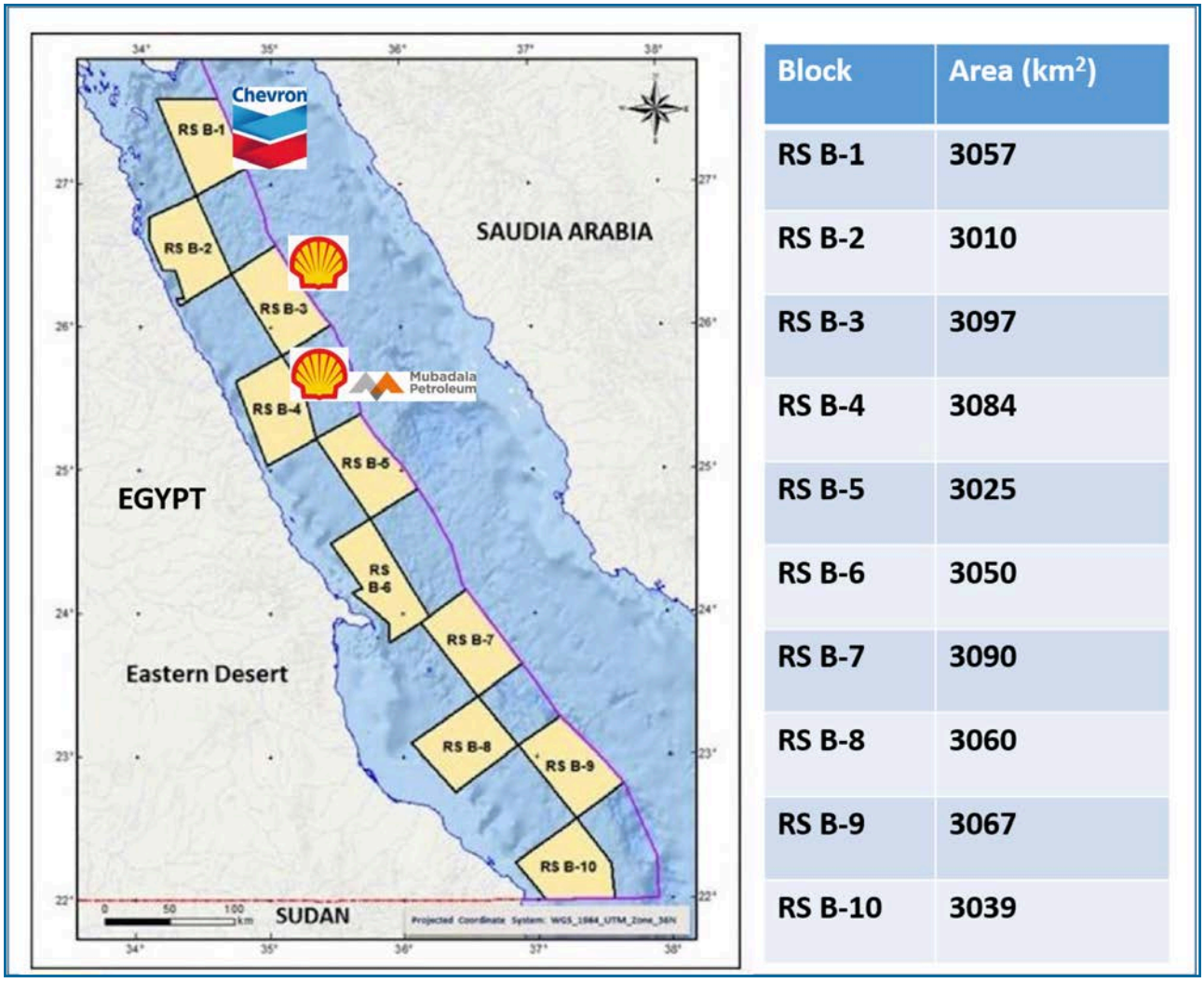


Figure 2. Exploration wells (green circles) in the Red Sea together with location of DSDP sites (black squares) and adjacent onshore basins



Block	Area (km²)
RS B-1	3057
RS B-2	3010
RS B-3	3097
RS B-4	3084
RS B-5	3025
RS B-6	3050
RS B-7	3090
RS B-8	3060
RS B-9	3067
RS B-10	3039

Figure 3. Offshore blocks on the Egyptian Red Sea

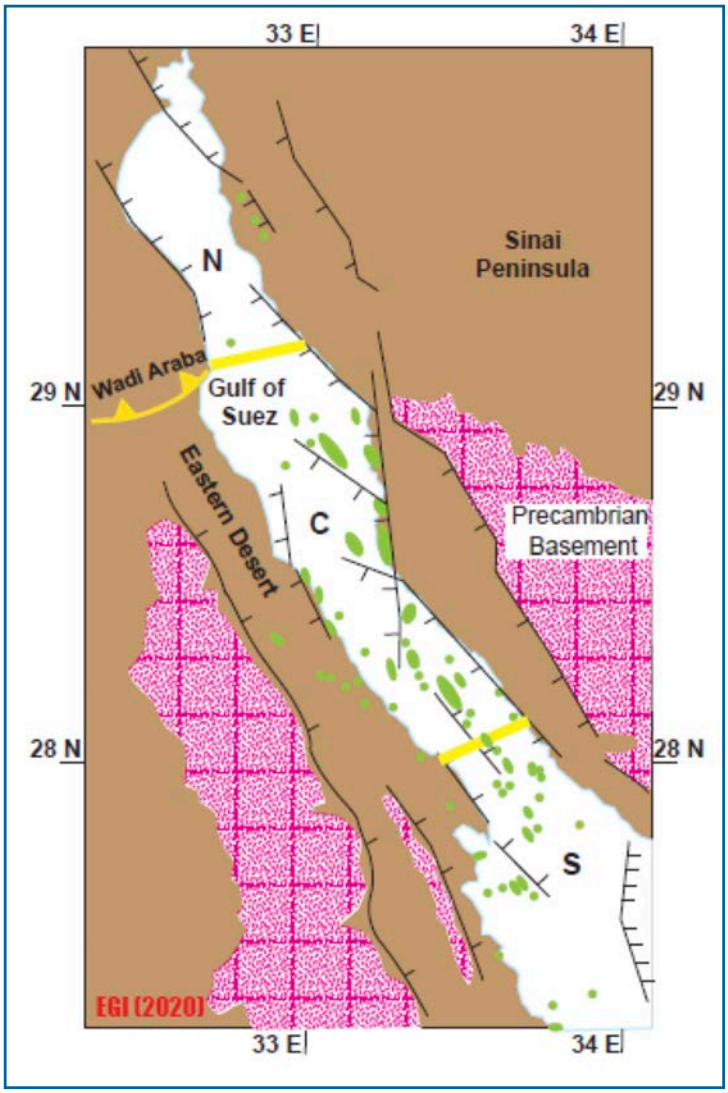
Various Tectono-sedimentary Scenarios

RSB rift structure is widely considered to be the northern arm of the Afar plume triple junction (Figure 1) that started in the Oligocene (~35 Ma) and developed into a juvenile oceanic crust at ~5 Ma. The other two arms of the Afar triple junction are the Gulf of Aden rift to the east, and the East African rift (EAR) system to the south. In this scenario, EAR is assumed to be the "failed arm." (Although lacking an ocean crust development yet, EAR is structurally, seismically, and volcanically active, and it is too soon to be called a "failed arm.")

RSB is a textbook rift system; indeed the term "Rift Valley" was first proposed by the British geologist J. W. Gregory (in 1896) for the East Africa rift and its extension to the Red Sea.

In the past 60 years, there has been a series of debates and discussions, partly conjectural and partly data driven, on the opening of the Red Sea. The various tectonic models for its genesis include: (1) Afar triple junction; (2) plume (single vs. multiple) impingements; (3) pull-apart extension related to transform faults; (4) simple shear asymmetric extension (Wernicke model); (5) pure shear symmetrical extension (Mackenzie model), and (6) crustal extension in response to slab-pull of the Neo-Tethyan oceanic crust in the Zagros belt.

Tectonic forcing of sedimentary evolution and facies distributions is well established in petroleum basins; therefore, it is important to decipher the various tectonic models for RSB. To do this, we will consider (1) internal structural framework and complexities in RSB, (2) the linkages of RSB to its surrounding structures: Dead Sea and Gulf of Suez to the north, the EAR to the south, and the Gulf of Aden to the east, and (3) relationships between the normal plate tectonics and the deep-seated plume tectonics in the region (for instance, the differences between the Afar triple junction and the Owen-Aden-Carlsberg triple junction, and their influences on the rifting processes).



Gulf of Suez as Guideline

The Gulf of Suez Basin (GSB) is the NNW branch of the deeper Red Sea. It thus offers a critical knowledge base on the structural and petroleum geology of the Red Sea. GSB is about 320 km long and 50–90 km wide between the Red Sea Hills and the basement uplift of Sinai, although the marine part is only 20–30 km wide. GSB already enjoys a successful history of petroleum discovery and production (Figure 4). Since the first oil discovery in 1908, nearly 1550 exploration wells have resulted in 170 fields. Of these, five are giant fields discovered between 1951–1974. In June 2020, Egypt's Ministry of Petroleum announced the discovery of an oil field (in the Geisum concession) in the southern part of GSB; the field is estimated to contain 70 million barrels of recoverable oil.

A very important feature of GSB petroleum systems is that they include both syn-rift (Oligocene-Present) and pre-rift (Cambrian-Eocene) sequences. There is also ample information on trap styles and relations between normal and transversal faulting (accommodation zones) in the basin. All these provide important insights for characterizing the structures and petroleum systems in RSB.

Figure 4. The Gulf of Suez and selected petroleum fields (in green). N (northern), C (central) and S (southern) sub-basins are separated by strike-slip structures (accommodation zones)

The development of the Aqaba-Dead Sea (Levant) transform fault (Figures 1 and 2) during middle-late Miocene has important bearings on both GSB and RSB. On the one hand, this structure formed a 105-km long left-lateral motion (associated with local pull-apart mini basins) as a new plate boundary for Arabia. On the other hand, its development put on an end on GSB rifting but widened the Red Sea opening.

Moreover, GSB is divided into several sub-basins separated by strike-slip accommodation structures (Figure 4). Three major sub-basins are the northern, central, and southern. The vast majority of petroleum fields (especially the giants) are located in the central sub-basin.

Research Tasks & Project Deliverables

1. A detailed analysis of the tectonic evolution of RSB based on evaluation of geologic and geophysical data and critical assessment of the various models already proposed. Including the impact of tectonics on sedimentary sequences and facies patterns in RSB.
2. Interpreting new seismic sections from key areas accessible to us.
3. High-resolution biostratigraphy of key source rock horizons based on new data and analyses from DSDP or other wells
4. Thermal maturity and hydrocarbon generation modeling of key areas based on wells, seismic and geochemical data
5. Geochemical typing of oil to source (using data contributed to this project)
6. Stratigraphic correlation (A) across RSB along the conjugate sides of the Red Sea, and (B) along the strike of RSB. The stratigraphic work will be based on wells. This correlative exercise will also be helpful to standardize the varied stratigraphic nomenclature of formations used in different basins or by different workers
7. Characterizing pre-rift sedimentary sequences (Jurassic-Eocene) and potential petroleum plays in RSB by projecting data from onshore basins and GSB wells
8. An examination of the geologic factors for the success of oil fields in GSB. Particular attention will be given to why numerous and giant fields are concentrated in the central sub-basin of GSB in contrast to other parts of GSB
9. Constructing paleofacies maps for key time horizons of source rock and reservoir rock deposition
10. Creating an atlas of seismic, stratigraphic, and well data for quick reference and use

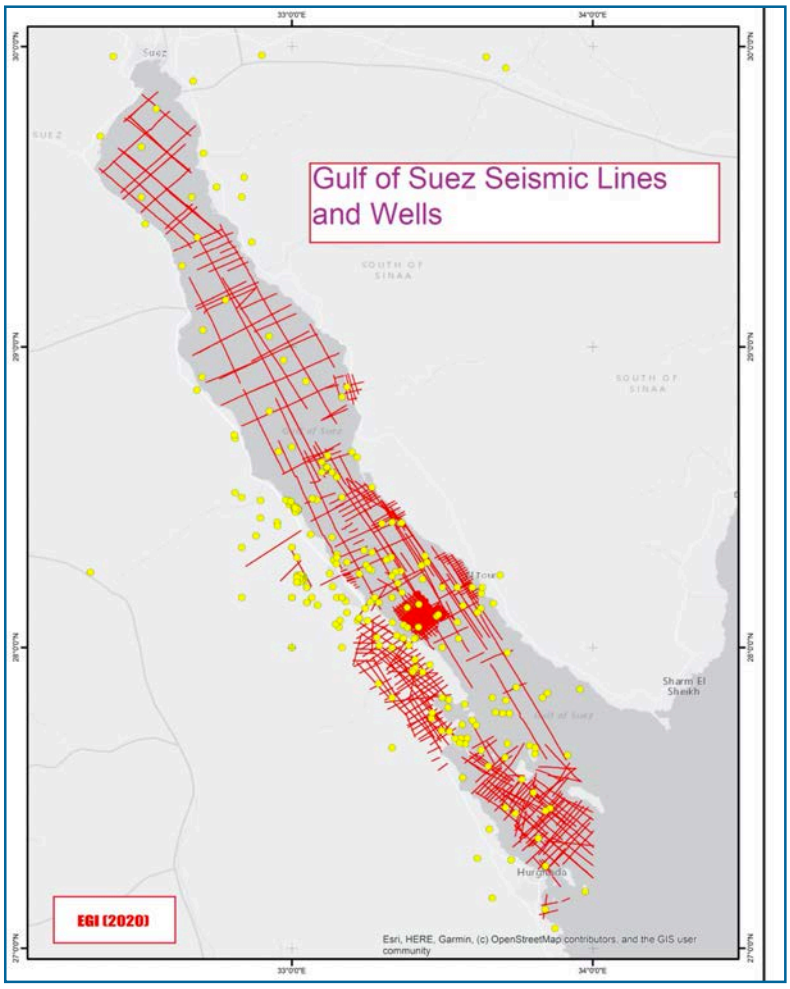


Figure 5. Seismic lines (red) and wells (yellow circles) from the Gulf of Suez basin

11. Play fairway mapping of hydrocarbon prospectivity in selected key areas based on a synthesis of information from wells, seismic, and other data
12. An annotated bibliography of publications and references
13. An ArcGIS package of the results and reports for easy access and use

Data Sources

To conduct the project, we will be using the necessary data from various sources including:

1. Well data and seismic lines contributed by our collaborators in Egypt, Yemen and Sudan;
2. Extensive mining of literature including research papers, university theses, company reports, conference presentations (>4000 sources)
3. Samples collected from DSDP or other wells for high-resolution stratigraphic and geochemical analysis;
4. In-house EGI reports and unpublished data. (Figure 5 shows our database for the Gulf of Suez.) In this work a group of experienced researchers in the region will be contributing to this project.

Research Team

Dr. Rasoul Sorkhabi	EGI Research Professor	Principal Investigator, Structural/ Seismic Interpretation, Paleofacies Mapping,Basin Modeling
Dr. Richardson 'Pitch' Allen	Research Professor	Regional Tectonics and Petroleum Systems
Dr. Dhrupad R. Beti	Post-doctoral Research Fellow	Petroleum Geochemistry, Pyrolysis
Dr. Sudeep Kanungo	EGI Research Associate & Adjunct Associate Professor	Paleoenvironment, Bio-Chronostratigraphy
Christopher Kesler	GIS Manager	GIS Analysis and Data Mapping
Dr. Bryony Richards	Senior Petrologist	Petrography and Mineralogy
Dr. Eiichi Setoyama	EGI Research Instructor	Paleoenvironment, Bio-Chronostratigraphy

Advisory and Consultancy Board and EGI Affiliate Scientists

Dr. Tony Doré	Global Chief Scientists Senior Advisor to the Director	Project Advisor
Tom O'Connor	EGI Affiliate Scientist	Geology, Egypt, Sudan
Dr. Mustafa As-Sauri	EGI Affiliate Scientist	Geology, Yemen
Dr. Cosmos Kujjo	Consultant	Sudan Consultancy
Dr. Henry Halpern	EGI Affiliate Scientist	Petroleum Geochemistry, Saudi Arabia, Egypt

Project Timeline, Investment & Report

The project will be conducted over the course of 18 months; start date to be determined.

The investment for this project is $74,000 (USD) per sponsor for the entire project.

EGI Technical Contact

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Research Team Bios

Rasoul Sorkhabi, Ph.D., Principal Investigator

Rasoul has worked on structural and petroleum geology of various basins including those in the Middle East, Yemen and East Africa. He has published widely. Together with Dr. Mustafa As-Saruri, he is completing a book on the petroleum geology of Yemen. Aside from the project management, Rasoul will conducing the structural/seismic interpretations, paleofacies mapping, and basin modeling.

Sudeep Kanugno, Ph.D., Bio-Chronostratigraphy

Sudeep is a nannofossil biostratigrapher, and is recognized for his work in applied chronostratigraphy through the graphic correlation methodology and composite standard database technology, which help identify and correlate periods of sedimentation, unconformities, and depositional environments in absolute time (mega-annum age).

Eiichi Setoyama, Ph.D., Bio-Chronostratigraphy

Eiichi has worked on Jurassic, Cretaceous, and Cenozoic sections, particularly on the North, Central, and South Atlantic margins, with a focus on the interpretation of biostratigraphy and paleoenvironment based on foraminifera. He utilizes graphic correlation and composite standard database for improved spatial and temporal calibration of stratigraphic ages and geologic events.

Dhrupad Raghuveer Beti, Ph.D., Petroleum Geochemistry and Pyrolysis

Dhrupad obtained his PhD in Chemical Engineering from the University of Utah in 2020 and has extensively worked and published on petroleum geochemistry and pyrolysis.

Dr. Bryony Richards,Ph.D., Petrography and Mineralogy

Bryony has extensively conducted research on high-resolution mineralogy, petrographic imagery, radiochemistry, and thermochronology. Her skills to solve complex geological problems add enormous value to this study.

Dr. Richardson (Pitch) Allen, Ph.D., Regional Tectonics and Petroleum Systems

Pitch is EGI's most senior scientist who has worked on petroleum basins and tectonics of various regions of the world including the Red Sea and Gulf of Suez. He brings in five decades of experience and knowledge to this study.

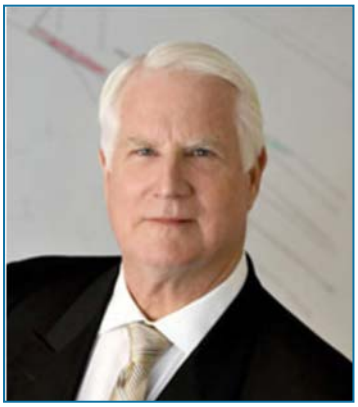
Christopher Kesler, B.S., GIS Analysis and Data Mapping

Christopher joined EGI in 1997 and has a degree in Geography/Geographic Information Systems from the University of Utah. He is an expert in GIS analysis and data mapping. He has worked on EGI projects in various parts of the world.

Advisory and Consultancy Board and EGI Affiliate Scientist Bios

Tony Dore, Ph.D., Chief Global Scientist, EGI

Tony obtained his PhD from University College London and joined the petroleum industry in 1977. He has 40 years of exploration and managerial experience, with multiple academic connections. His 70+ publications, including seven co-edited books, have covered diverse subjects including passive margin evolution, broad-scale paleotectonic reconstruction, and petroleum systems.



Thomas O'Connor, MS. Expert areas: Egypt and Sudan

Tom graduated in geology from Stanford and University of Colorado. He has decades of experience in the oil and gas industry especially Egypt and Sudan in managing projects and and mentoring companies.

Mustafa As-Saruri, Ph.D., D.Sc. Expert area: Yemen.

Mustafa has degrees in geology from his native Yemen. He continued his doctoral and post-doctoral studied in Germany where he obtained Ph.D. and D.Sc. in geology from Ernst-Moritz-Arndt University. He has worked for Geological Survey in both Aden and San's (1975-2000) and Yemen's Petroleum Exploration and Production Authority (2000-). He conducted research at EGI as a Fulbright Fellow (1993-94). He has published a large number of research papers, including some with Rasoul; they are currently completing a book on the petroleum geology of Yemen.

Cosmas Kujjo, Ph.D., Consultancy on Sudan.

Dr. Kujjo hold a PhD in geosciences from the University of Kentucky and served at Geological Research Authority and then Directory General of Ministry of Petroleum and Mining in Sudan and South Sudan (1988-2018).

Henry Halpen, Ph.D., Petroleum Geochemistry. Expert areas: Saudi Arabia and Egypt.

Henry has PhD in organic geochemistry from UCLA and has worked for Saudi Aramco for twenty years (1992-2012). He has also served as consultant for ConocoPhillips, StratoChem (Egypt) and other companies.

EGI Sponsorship & Contract Information

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