

IN DEVELOPMENT

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Investment per Sponsor

\$89k (USD) – Upon signing

\$86k (USD) – Start of year 2

(\$175k USD total)

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Hybrid Unconventional Non-marine Plays in Asia-Pacific

Geology, Play Identification & Hydrocarbon Systems in China, Indonesia & Australia

VALUE

- An expanded understanding for basin-specific geologic, geochemical and mineralogical knowledge of non-marine strata in major producing Asia-Pacific onshore basins with producing or potential unconventional plays
- Define basin evolution and the development of non-marine petroleum system elements including prioritized geological controls related to unconventional accumulation and production
- Generate predictive non-marine models for play habitat of stratigraphically associated hybrid unconventional tight sand/ carbonate, shale and CBM hydrocarbon systems
- Characterization of unconventional plays via data integration, interpretation, analysis of sample tests and comparisons U.S. analog unconventional plays
- An evaluation of unconventional non-marine play opportunities

KEY DELIVERABLES

1. ArcGIS based database including stratigraphic charts, structural and depositional evolution maps, atlas of oil/gas fields, maps of petroleum system elements and charts, petroleum system modeling, play fairways maps for hybrid unconventional non-marine plays, spreadsheets of sample tests, reservoir characterization of representative hybrid unconventional plays, and models for play concepts.
2. Preliminary assessment of risk for each petroleum system including reservoir and source rock distribution.
3. Data uploads, quarterly updates, meeting presentations, final project report text and figures.

PROJECT RATIONALE & MOTIVATION

The commercial successes of tight sand gas, tight oil, CBM and shale gas in North America have triggered the exploration of unconventional plays in dozens of countries around the world. In the last decade, the industry and academic institutions have been focusing on the shale oil and shale plays. Studies and E&P results indicate that many of the so-called shale reservoirs are actually hybrid tight reservoirs (not a pure shale play) and many tight sand plays are associated with organic-rich shale plays. We define “Hybrid Plays” as all the stratigraphically associated shale, siltstone, sandstone, carbonate and CBM plays within a specific stratigraphic interval containing hydrocarbon source rocks.

U.S. examples of hybrid plays are the tight oil production in the Permian Basin coming from stacked tight Wolfcamp and Spraberry plays and Cline shale plays. The Bakken play consists of Middle Bakken tight carbonate and sandstone plays and Upper and Lower Bakken shale plays. The Eagle Ford play includes interbedded carbonate and shale. These hybrid plays often have a strong stratigraphic association and are fine-grained in nature. For the non-marine strata in a basin, the shale, sandstone and coal measures commonly alternate and are in communication both laterally and vertically. On a global scale various data sources indicate the Asia-Pacific region ranks No. 1 in terms of remaining, technically recoverable, unconventional gas plays (shale gas, CBM, tight gas) (Figure 1). Most of the unconventional plays in the Asia-Pacific region are non-marine depositional systems in basins formed after the breakup of Pangaea. These non-marine basins have long histories as productive conventional basins and all are proven, active petroleum systems containing world-class, non-marine source rocks and large conventional hydrocarbon accumulations. The tight fluvial sands, coal beds and organic-rich lacustrine shales have stratigraphic associations and were deposited in non-marine settings. Potential hybrid unconventional plays are widely distributed in non-marine basins in the Asia-Pacific region (Figure 2) and have become hot spots for unconventional exploration in recent years.

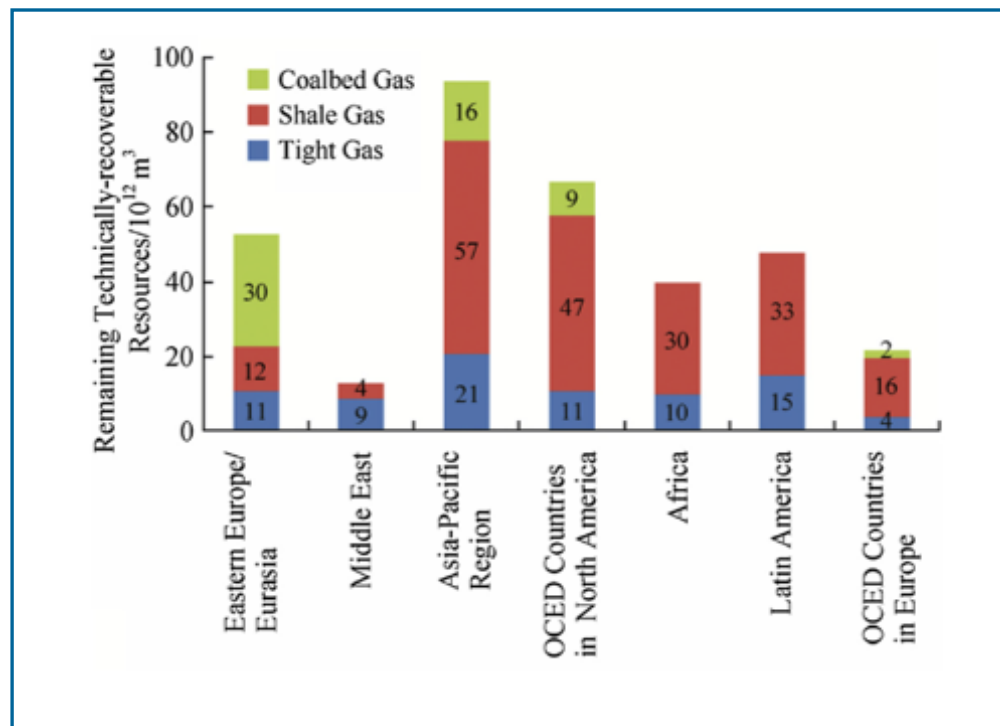


Figure 1. Remaining technically recoverable unconventional resource in the world (Jia et al., 2014).

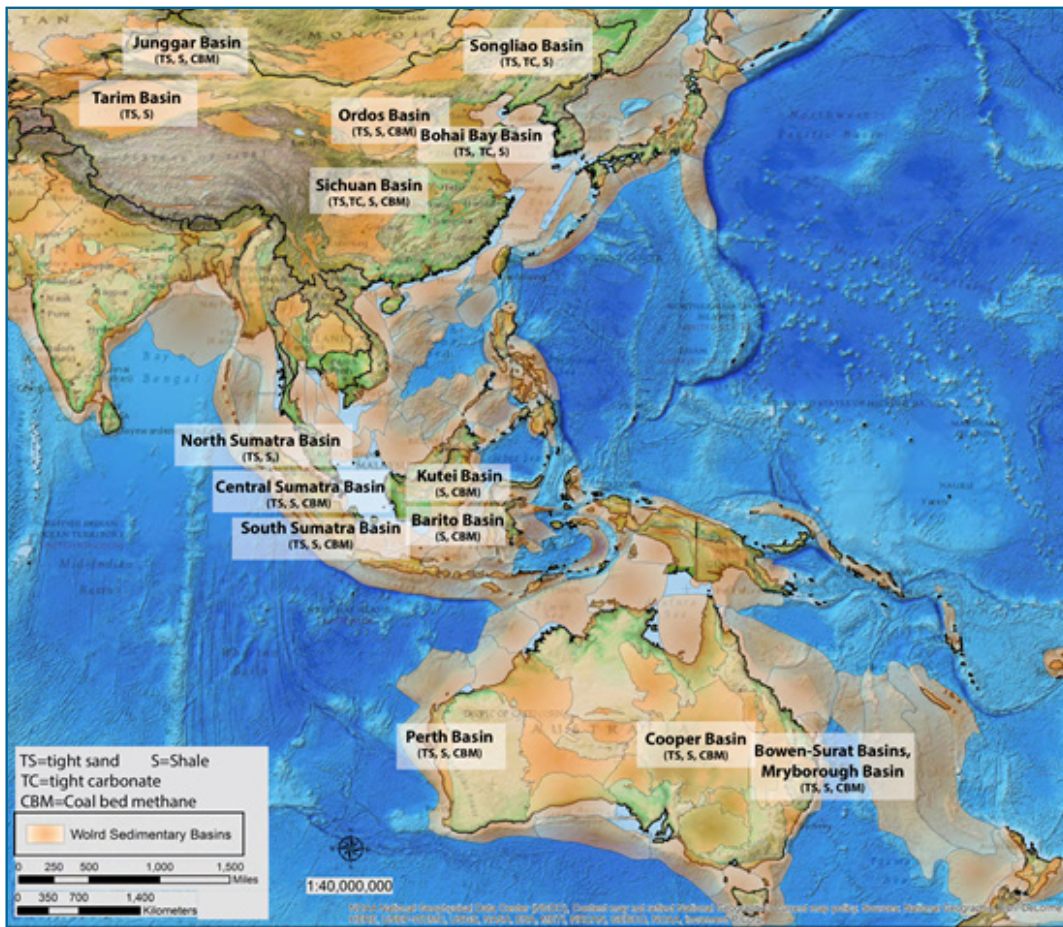


Figure 2. Key hybrid unconventional plays in non-marine onshore basins in Asia-Pacific.

For the onshore basins in the Asia-Pacific region, Chinese, Indonesian and Australian basins dominate the discovered hydrocarbons and have huge remaining unconventional resources. China and Australia are leading lacustrine shale exploration efforts and compared to the U.S., China, Australia and Indonesia have huge, world-class CBM and tight sand reserves. High E&P potential exists for unconventional systems as demonstrated by proven tight gas production and preliminary CBM production in China, Indonesia and Australia and emerging lacustrine shale gas plays in China and Australia. Results from EGI's two-phase "China Shale Gas and Shale Oil Plays" research and recent unconventional exploration activities in China indicate production is from tight carbonate or siliciclastic reservoirs that are often juxtaposed against or interbedded with organic-rich shale or coal measure source rocks. The associated shale or coal also has preliminary production or good hydrocarbon shows in Cooper Basin, Australia and the Ordos and Sichuan basins in China. Generally, the production from lacustrine shales is not fully commercial due to heterogeneity, the clay-rich nature of some lacustrine shales, few studies focused on unconventional geology, historically low exploration levels in lacustrine basins, and the challenge of stimulation techniques and producibility. Many companies either do not have or have only limited rock property data that are crucial for understanding this reservoir type.

Recent production from Jurassic lacustrine shale and tight carbonate reservoirs in the Sichuan Basin (southwest China) and preliminary production from Permian lacustrine shale in Cooper Basin imply the huge, untapped potential of unconventional hybrid plays in lacustrine basin. The shale resource plays, tight sands or carbonate plays and CBM plays coexist in many of these Asia-Pacific basins.

Huge unconventional resource potentials, proven producing basins, primary unconventional production, high demand, existing infrastructure, favorable policies and high domestic gas price high-grade China, Indonesia and Australia as three countries on which to focus our research. Based on our previous studies for China shale plays and current sample testing of lacustrine shales from Cooper Basin in Australia, EGI is proposing further investigation for hybrid petroleum systems in Asia-Pacific to provide our Corporate Associate members working in these areas an atlas of stratigraphically associated resource plays and exploration recommendations.

OBJECTIVES

- Improve basin-specific geologic, geochemical and mineralogical knowledge of non-marine strata in major producing Asia-Pacific onshore basins with producing or potential unconventional plays.
- Relate the basin evolution to development of non-marine petroleum system elements.
- Characterize properties of unconventional plays through data integration, interpretation and analysis of sample tests.
- Understand the similarities and differences in non-marine unconventional plays and on a regional basis determine analogs to typical U.S. unconventional plays.
- Generate predictive non-marine models for play habitat of stratigraphically associated hybrid unconventional tight sand/carbonate, shale and CBM hydrocarbon systems.
- Investigate and prioritize geological controls on unconventional accumulation and production.
- Recommended unconventional play opportunities.

SCOPE OF WORK

1. Collect, compile, archive and interpret data of non-marine onshore Sichuan, Ordos, Bohai Bay and Tarim Basins in China, Cooper Basin in Australia, and Central Sumatra Basin, South Sumatra Basin, Kutei Basin and Tarakan Basin in Indonesia through collaborative and holistic approaches.
2. Conduct basin analysis, tectono-sequence stratigraphic analysis, depositional study and petroleum system analysis;
3. Identification of stratigraphically associated hybrid shales, tight carbonate and siliciclastic systems, and CBM plays in key onshore non-marine basins in Asia-Pacific;
4. Geologically characterize the non-marine unconventional plays in terms of stratigraphic association, depositional facies, environment of deposition, rock types, and rock properties.
5. Sample tests for geochemistry, mineralogy, rock fabrics, petrophysics.
6. Map the regional trends for key properties (facies, reservoir thickness, mineralogy, geochemistry, etc.) for potential target zones of hybrid unconventional plays.
7. Characterization and evaluation of hybrid unconventional plays in Asia-Pacific and comparison of key properties between these unconventional plays and typical unconventional plays in U.S.
8. Basin wide petroleum system analysis for unconventional plays based on source-accumulated hydrocarbons correlation and petroleum system modeling integrating geology, geophysics, outcrop, wells and geochemistry.
9. Characterize producing and emerging plays, and create a catalog of unconventional plays for each type of basin and reservoir, and integrate the analysis of a representative sample of recently drilled wells.

10. Generate robust play concepts and predict new exploration opportunities (stacked plays and favorable areas) by play fairway techniques and mapping.
11. Comparative study for unconventional plays different depositional settings and basins.
12. Provide ArcGIS database.

DELIVERABLES

1. Data uploads, quarterly updates, meeting presentations, final project report text and figures.
2. ArcGIS based database including stratigraphic charts, structural and depositional evolution maps, atlas of oil/gas fields, maps of petroleum system elements and charts, petroleum system modeling, play fairways maps for hybrid unconventional non-marine plays, spreadsheets of sample tests, reservoir characterization of representative hybrid unconventional plays, and models for play concepts.

PROJECT TIMELINE & INVESTMENT

The duration of the project is 24 months and will commence when contracts are received. Three project meetings (kick-off, mid-term, and final) will be held during the project to report progress and invite discussions. Quarterly updates and interim data uploads will be provided to all sponsors.

Investment per sponsor is anticipated to be \$175,341 (USD).

- \$89,000 (USD) Due upon signing (Year 1)
- \$86,000 (USD) Due at the start of Year 2

RESEARCH TEAM

Staff	Expertise/ Affiliation
Shu Jiang, Ph.D., Principal Investigator	Regional study, Depositional Systems, Petroleum System & Unconventional Reservoir Characterization (EGI)
John Conolly, Ph.D., Co-Principal Investigator	Australian Geology Expertise (EGI)
Raymond Levey, Ph.D., Director & Project Advisor	Unconventional Geology & Resource Assessment (EGI)
Bryony Richards, Ph.D., Senior Petrologist	Petrology, Geochemistry, Reservoir Characterization (EGI)
Fengde Zhou, Ph.D., Research Associate	Reservoir Geology & CBM (University of Queensland)
Jinchuan Zhang, Professor	Leading Scientist–Unconventional Reservoirs in China (China University of Geosciences at Beijing)
Youliang Feng, Ph.D., Senior Geologist	Experienced Petroleum Geologist & Sedimentologist (Consultant in Beijing)
2 Ph.D. Candidates & 2 M.Sc. students	TBD
Christopher Kesler (B.A.)	GIS mapping (EGI)

EGI TECHNICAL CONTACTS

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Research Interests

- Petroleum geology for conventional and unconventional resources
- Geothermal geology
- Sequence stratigraphy
- Basin analysis
- Lacustrine to deepwater sedimentary geology
- Petroleum systems
- Reservoir characterization
- Lacustrine to deepwater depositional systems
- Seismic interpretation integration of geology, geophysics, geochemistry, and engineering

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Shu Jiang, PhD

RESEARCH ASSOCIATE PROFESSOR

COORDINATOR FOR CHINA PROGRAM DEVELOPMENT

Senior Research Scientist and Research Associate Professor Shu Jiang joined EGI in 2010. He earned his Ph.D. in Petroleum Geology from China University of Geosciences at Wuhan and completed postdoctoral research at the University of Colorado at Boulder. He worked at CNOOC in Beijing for two years where he was involved in a significant gas discovery in Bohai Bay, China.

Shu has over 20 years experience in petroleum geology, sedimentary geology, basin analysis, sequence stratigraphy, petroleum systems, lacustrine to deepwater depositional systems, and unconventional reservoirs research spanning geology, geochemistry, geophysics and petroleum engineering. He is a Certified Petroleum Geologist (CPG), active member of AAPG, SEG, IAS, and GSA and has more than 90 publications to his credit. He also serves as an Advisory Member of the AAPG Shale Gas & Liquids Committee and has convened and chaired many international meetings.

Sequence Stratigraphy, Basin Analysis & Petroleum Systems for Conventional and Unconventional Reservoir Prediction

Shu conducts innovative and applied research in sequence stratigraphy and basin analysis in various tectonic settings by integrating core, well logs, seismic data, outcrop, etc. He proposes practical depositional models and suggest potential drilling targets for both conventional and unconventional reservoirs by integrating petroleum system analysis.

Lacustrine to Deepwater Depositional Systems

Shu's studies include the ancient and modern lacustrine to deepwater siliciclastic sediments transportation from source to sink and characterization of spatial and temporal evolution of depositional element architecture to predict deepwater reservoirs. Projects integrate structural, sedimentological and geomorphic studies and bridge both fundamental and petroleum geosciences.

Reservoir Description & Characterization

His work achieves successful reservoir model characterization by accurate property and architecture of all the siliciclastic depositional elements and uses state-of-the-art interpretation tools on a wide range of outcrop and subsurface data-sets to predict stratigraphic occurrence, 3-D geometry, and geophysical attributes of sandstone, CMB and shale reservoirs from lacustrine to deepwater setting.

Global Experience

Shu has worldwide industry and academic experiences from continental to deepwater setting basins (from East China lacustrine rifted basins, Northern China Cratonic basin, West China foreland basins, to South China Sea passive margin basin, basins in SE Asia, the Rocky Mountains, onshore Africa, and South America ,through deepwater GOM, Angola, Australia basins).



John Conolly, PhD

AFFILIATE SCIENTIST

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Research Interests

- Global exploration in frontier basins
- Peer assists in basin analysis
- Risk analysis of petroleum systems
- Australian, P.N.G. & New Zealand geology

EGI Affiliate Scientist Dr. John Conolly was the key scientist who developed the seminal proposal to evaluate rift systems of North Africa that was funded by the National Science Foundation in 1972. He was instrumental in helping to establish EGI in its founding in 1972 as the Earth Science and Resources Institute (ESRI) at the University of South Carolina. Currently Managing Director of Petrofocus Consulting, John has 50 years experience in exploration of frontier basins worldwide.

John participated in the now famous Baltimore Canyon Trough Lease Sales and was a successful bidder for offshore acreage with Shell U.S.A., the major participant and operator. As a Principal of the frontier basin ventures, primarily as the 'innovator' and 'instigator' of these ventures, his work included all of the new joint ventures put together by the Sydney Oil Company during the period 1977 to 1988. These resulted in the participation in the discovery of fourteen new oil fields including the South Pepper, North Herald trend on the Northwest Shelf, and the Fairymount, Bodalla South, and Nockatunga trends in Queensland. Since 1988, he has worked as an independent consultant, creating new frontier plays and putting together new acreage blocks in the Northwest Shelf and other basins in Australia, Papua New Guinea, the Philippines, the S.W. Pacific Islands, and New Zealand.

John's work has spanned the globe and includes affiliations with such entities as the U.S. Naval Oceanographic Office, Scripps Institution of Oceanography, Lamont Doherty Geological Observatory at Columbia University, and numerous major partners in the energy industry and government agencies throughout Australia, New Zealand, South Pacific Islands, and the United States. He also founded Rawson Resources Ltd., an active oil explorer listed on the Australian Stock Exchange in 2005.

John has over 50 years of experience as a geologist and researcher in the energy and geosciences industry. He received a B.Sc. from the University of Sydney (1958) and his M.Sc. and Ph.D. from the University of New South Wales (1960, 1963). Between 1965 and 1971, he served as Professor of Geology at Louisiana State University, Columbia University, N.Y., and the University of South Carolina. John has been the recipient of numerous awards and honors spanning his distinguished career and is credited with over 100 articles in journals, conferences, and short courses. He was Keynote speaker to APG Conference India, in 2004 and 2006 and is an active member of the Petroleum Exploration Society of Australia and the American Association of Petroleum Geologists.

Dr. Conolly represents EGI in Austral-Asia and is actively involved with key research in sheared margins of Western Australia and in developing EGI's role in shale systems research across the Australian continent. He also conducts short course trainings and field courses for EGI Corporate Associate members.

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