



Advanced Resources International (ARI) has worked on unconventional oil and gas resources for the U.S. Department of Energy since 1980, publishing an extensive variety of papers and studies ranging from resource evaluation to government policy to environmental protection technologies.

Outside of our primary focus in the USA and Canada, we also have worked extensively in some 30 other countries, including well site testing and operations in Australia, China, Chile, India, Indonesia, Poland, South Africa and Zimbabwe.

## Unconventional Resources

### General Unconventional Gas

**Private Client: Unconventional Gas Economics and Modeling: North America.** ARI has been assisting clients for the past two years to evaluate and model the economics of unconventional natural gas development (including coalbed methane) in North America. ARI is using an advanced proprietary version of our North America unconventional gas model that we originally built for the U.S. Department of Energy.

**Asia-Pacific Economic Cooperation (APEC): Evaluation Study: APEC Economies.** For APEC's Energy Working Group, ARI conducted the study, "APEC Unconventional Gas Census: Evaluating the Potential for Unconventional Gas Resources to Increase Gas Production and Contribute to Reduced CO<sub>2</sub> Emissions", which provides an in-depth look at each APEC Economy's: (1) current unconventional gas production; (2) officially assessed size of its unconventional gas resource base; and (3) estimate of future volumes of unconventional gas production.

**American Petroleum Institute (API): Guidance Documents:** Prepared a three volume series of environmental guidance documents related to hydraulic fracturing operations for use by industry and governmental personnel to understand industry "best practices" for hydraulic fracturing operations. The titles were Hydraulic Fracturing Operations-Well Construction and Integrity Guidelines (API HF1, First Edition/October 2009), Water Management Associated with Hydraulic Fracturing (API HF2, First Edition/June 2010), and Practices for Mitigating Surface Impacts Associated with Hydraulic Fracturing (API HF3, First Edition/January 2011).



## Shale Gas

**U.S. Energy Information Administration: World Shale Gas and Shale Oil Resource Assessment: 7 Continents.** In 2011 and again in 2013, ARI conducted the first “global” studies of shale oil and gas resources, for the U.S. Department of Energy’s Energy Information Administration. ARI conducted extensive literature review and analysis of source rock shales, synthesized geologic data on global shale formations, and then mapped and rigorously quantified the shale oil and gas potential in 41 of the most promising countries, developing over 200 original geologic maps. While we still consider the study to be highly preliminary, it has received considerable attention, including reports in the Economist, Wall Street Journal, New York Times and other media. Several of our Major Oil clients are using the EIA-ARI study as a source to guide their global shale exploration efforts.

**Japan Bank for International Cooperation (JBIC); Shale Play Evaluation: North America.** ARI prepared a report on the North American shale gas industry, addressing the geology, technology, economics, and environmental impacts of shale gas development. We evaluated the Barnett, Hayneville, Marcellus, and other shale gas plays and profiled many of the leading shale gas exploration and production companies. Subsequently, ARI prepared a report focusing on “liquids-rich” (oil-producing) shale reservoirs. The scope included North America Europe, Asia, South America, Africa, and Australia. Finally, ARI provided several studies providing perspectives on the federal and state regulatory and public policy outlook for shale development in the United States.

**Alberta Department of Energy: Oil and Gas Studies: Canada.** During 2006 through 2011 ARI conducted two studies of unconventional oil and gas developments in the USA for the Alberta Department of Energy. In many ways, Canada and particularly Alberta has been negatively affected by the shale revolutions in the USA, a long-time market for Canadian production. One of our studies assessed the geology, production, and economics of all USA shale gas and oil plays. The Alberta DOE has adjusted its royalty regime using information from our studies.

**BG Group: Shale Oil and Gas Study: USA.** Starting in 2008 ARI evaluated all USA shale oil and gas plays for BG Group (UK), again covering geologic, drilling, completion, fracturing, reservoir, and production analysis. First we conducted training on shale oil and gas geology and technology, since BG had never been involved with shale before. We visited the Chesapeake Energy data rooms with our client. We high-graded various plays and made recommendations as to optimal sub-plays and operating partners. This work provided the basis for BG’s subsequent \$2 billion joint-venture deals with Exco Resources in the Haynesville Shale dry gas play of Louisiana and the Marcellus Shale dry and wet gas plays of Pennsylvania and West Virginia. Early in 2013 we assisted BG by calculating the asset valuation of certain Louisiana properties which BG later successfully sold to Exco. At present we continue to assist BG Group on shale oil exploration in new areas of the USA.

**Private Client: Shale Oil and Gas Study: USA.** Starting in 2010 ARI evaluated all USA shale oil and gas plays for client. This included geologic, drilling, completion, fracturing, reservoir, and production analysis. First we conducted training on shale oil and gas geology and technology, since client had never been involved with shale before. We then high-graded various plays and made recommendations as to optimal sub-plays and operating partners. This work provided the basis for client’s subsequent farm-in



deal with another company in the emerging liquids-rich eastern U.S. shale area. At present we continue to assist client on shale oil exploration in new areas of the USA.

## Coalbed Methane

**U.S. Trade and Development Agency: Feasibility Study: Turkey.** ARI completed a feasibility study for Hema Dogal Enerji Kaynaklari (HEMA), that examined the technical and economic aspects of developing coalbed methane (CBM) on HEMA's CBM license areas in northern Turkey. The study assessed the in-place resource base and the technically recoverable reserves, developed a well drilling and completion strategy, evaluated end-use options for the gas, and examined the legal, regulatory, and environmental aspects of CBM in the country.

**U.S. Environmental Protection Agency, Coalbed Methane Outreach Program (CMOP):** Technical Outreach and Support: U.S. and International. Since 2000, ARI has been a prime contractor for U.S. EPA's CMOP Program providing a wide variety of support work including: Supported EPA's efforts under the Global Methane Initiative (GMI) program through working with other partner countries in developing project opportunity materials for the project expos in New Delhi and Beijing. Work entailed technical support and arranging travel and visits for foreign participants. Assisted with the establishment of the CMM Clearinghouse in Ranchi, India. Work entailed technical support and facilitation of meetings with CMPDI and other relevant government personnel. Conducted two major CMM feasibility studies in China (Hebi #6 mine and the Liuzhang mine). These studies entailed estimating CMM resources, developing a detailed reservoir simulation model, designing more effective degasification technologies using long hole directional drilling technologies, market assessments, end-use technology, and economics. Performed quick turnaround technical and economic assessments for EPA outreach efforts with coal companies (notably Cliffs). These studies compared the economics of flaring to small-scale power generation. ARI produces all of the EPA Coalbed Extra newsletters and has composed the latest EPA Gassy Mines Profile. ARI makes presentations on CMM degasification techniques at major international conferences in Poland, India, and China.

**U.S. Trade and Development Agency/ Georgia International Energy Corporation: Degasification Program Development: Georgia.** In 2008, ARI undertook the project: "Developing a Degasification Program for the Tkibuli-Shaori and Vale coal mines, Georgia". Specific tasks performed under the contract included: (1) Provided engineering design for the drilling, completion, and production of the first CMM wells drilled in Georgia at the Tribuli-Shaori mine; (2) Assisted GIEC in writing a successful feasibility study grant proposal from TDA; (3) Performed market assessments for the end-use of the gas; (4) Designed surface facilities for the collection, processing, and transportation of the gas; and (5) Provided on-site geologic and engineering support during drilling and testing

**Amcoal: Pre-Feasibility Study: South Africa.** ARI played a lead role in the pre-feasibility study for the development of the Waterberg CBM field located in the Republic of South Africa. During the course of the study, and working with Anglo Coal experts, cost estimates for all aspects of the project including drilling and completion, surface facilities, water and gas gathering and measurement facilities, and compression and transmission pipeline design were developed.

**Asian Development Bank/MIGAS: CBM Evaluation: Indonesia.** Rigorous evaluation of CBM resources in Indonesia, identifying over 450 Tcf of prospective gas in-place and the principal CBM basin



sweet spots. From 1999 to ARI personnel conducted major technical assistance projects for ADB that had significant impact on unconventional gas development in China and Indonesia. The China advisory projects culminated in ADB's successful loan of \$110 million to help Jincheng Coal Group construct the world's largest CMM-to-Power station at Jincheng, Shanxi. The Indonesia project helped MIGAS to develop the country's coalbed methane PSC system, resulting in over 30 PSC's awarded to CBM operators to date.

**Teck Alaska: Development Program: U.S.** ARI worked with Teck Alaska in developing the extensive gas shale resources around the Red Dog Mine, Alaska. ARI managed the entire exploration program including the coring and testing, well testing, hydraulic fracturing, production operations, and reservoir simulation.

**Vale Coal: CBM Geologic and Engineering: Mozambique.** ARI project, Pre-mine Degasification at the Moatize Coal Mine, Tete, Mozambique, included designing wells, artificial lift and surface facilities, gathering and metering systems for a 30 well development to provide 30 mW of power for mine startup operations. Detailed capital and operating cost estimates were determined for budgeting purposes based on actual quotes and ARI's cost data base. Procured all of the specialized equipment to conduct the field testing for a five well pilot. Produced a bankable feasibility study for management to move the project forward. Conducted training and technology transfer workshops for Vale employees and examined a range of end-use options for the gas in this remote setting.

**United Nations Development Program (UNDP) CBM Training: China.** From 1993 to 1994 ARI assisted China's Ministry of Geology and Mineral Resources (former) and Ministry of Coal (former) to learn modern CBM technology and procure specialized drilling and testing equipment. ARI evaluated multiple CBM areas across China, identifying the Liulin pilot site in the Ordos Basin as a sweet spot. Today, Liulin is a national-level CBM commercial demonstration project with over 100 production wells drilled by CUCBM-CNOOC, Fortune Oil, and Dart Energy.

**Altos Hornos de Mexico, S.A. de C.V. (AHMSA): Unconventional Gas Consulting: Mexico.** ARI reviewed and gave recommendations for a Regulation on Proving Gas Association with Coal document entitled "Technical Provisions for Performing the Studies Required for Proving Gas Association with Coal Deposits," a regulation proposed by the Secretaria de Energía (SENER) (Mexican Secretary of Energy), Federal Government of Mexico.

**Empresa Nacional Del Petroleo (ENAP): Well Testing Operations: Chile.** In 2009-2010 Chile's national oil company ENAP engaged ARI to design and supervise a CBM well testing operation in the Magallanes, at the sweet spot previously located by ARI, representing the first CBM pilot in the country. ARI's work included gas content and permeability testing followed by hydraulic fracturing and production operations. ARI also conducted CBM training and technology transfer for ENAP.

**U.S. Trade and Development Agency/Donetsk Regional Administration; CMM/CBM Feasibility Study: Ukraine.** From 2004 through 2008, ARI undertook the project "Coalmine Methane and Coalbed Methane Development in the Donetsk Region, Ukraine." The contract scope and responsibilities included: (1) Developed new drilling and degasification techniques for CMM production at the Bazhanov and South Donbass #3 coal mines near Donetsk; (2) Provided an assessment of CMM/CBM resources that could be exploited; (3) Developed drilling, completion, and production designs for both subsurface and above





ground facilities; (4) Conducted a market assessment of the produced gas; (5) Conducted economic and financial analyses of the different projects including an analysis of carbon credit potential; and (6) Completed an environmental assessment for the project.

**Companhia Vale Rio Doce (CVRD): Pilot Well Testing Program: Mozambique.** For CVRD's Moatize coalfield project, ARI developed a pilot well testing program for CBM development. In 2008, we completed the geologic analysis and gas content testing and desorption work on a series of coreholes. Using this data, we performed reservoir simulations to predict 20 year gas and water recoveries from the wells which served as the basis to perform financial and economic on using CBM to fire a 15-20 MW power plant. ARI conducted an injection/falloff test in the wells to determine permeability and other critical reservoir parameters governing CBM production. This was followed up by a 5 well pilot production project for which ARI provided all of the engineering design and oversight and production operations.

**PGT Queensland Pipeline, CBM Reserve Audit, Australia.** ARI performed reserve audits of Tipperary's Comet Ridge coalbed methane project in Queensland in support of pipeline planning. We also conducted a cost benchmarking of Australian vs. U.S. coalbed methane development costs and helped develop strategies for improving CBM economics.

**European Investment Bank/AfPenn Exploration: CBM Feasibility Study: Zimbabwe.** Conducted a \$1.0 million program funded by the European Investment Bank to assess the feasibility of producing CBM in Zimbabwe for fueling a 240 MW power plant. ARI provided capital and operating cost estimates and economics and the results of the work were presented in a bankable feasibility study International Finance Corp. (IFC) and the Industrial Development Corp. (IDC) of South Africa.

**Botswana Department of Geologic Survey (DGS): Geologic Assessment Study.** In 2001, we were awarded a \$1.5 million contract from the DGS to evaluate Botswana's CBM resources. The work includes detailed geologic assessments of two potential areas, coring and testing four coreholes for gas content and permeability, geophysical cogging, basin modeling, reservoir simulation, and economic and financial studies. The study represents the only national assessment of Botswana's vast coal resources and has been the primary data source for the more than a dozen companies that have acquired CBM leases in Botswana.

**CNPC and Beijing Gas Transmission Company: Feasibility Study: China.** For CNPC and Beijing Gas Transmission Company, ARI prepared a detailed feasibility study and design for the first gas storage field in China. This involved detailed petrophysical and geophysical analysis, reservoir simulation and history matching, and field design and operation procedures.

**U.S. Trade and Development Agency/Essar Oil: Feasibility Study: India.** ARI was awarded a \$300,000 feasibility study on a sole source basis to assess the CBM resources of the Mehsana coal bed methane leasehold in Gujarat State. The study included geologic assessment, reservoir engineering, well completion and stimulation design, surface facility design, costing, and economic and financial analysis.

**BG Group: CBM Evaluation: Scotland.** ARI thoroughly evaluated Composite's Scotland CBM project, which BG was funding. ARI conducted geologic analysis, reservoir simulation and production engineering reviews which supported BG's decision to exit this failing CBM project (which had come highly recommended by the London-based consultancy which had previously advised BG). ARI also



provided CBM evaluation support to BG on other countries in Europe and Asia-Pacific which remain confidential at this time.

**Gas Corporation of Botswana (BGC): CBM Pilot Well Testing Program:** ARI was commissioned to undertake all the consultancy aspects for CBM exploration of the BGC leases in Eastern Botswana including drilling, well testing, gas desorption, reservoir simulation, and resource assessment. Provided on-site geologic and engineering support during the drilling and testing of four core/test well. BGC leases were rolled into Kalahari Energy.

**BG Group Training, Corporate Strategy, and Acquisition of Queensland Gas Corp (Australia).** During 2005 to 2008, ARI supported BG Group on a business unit- and eventually CEO-level study of the global CBM industry. ARI helped BG to develop and successfully implement a corporate entry strategy that has given the company a material global CBM business unit.

BG previously had no corporate experience in coalbed methane, apart from funding Composite Energy's CBM exploration project in Scotland. Thus, ARI's work for BG began with extensive training on all aspects of CBM technology and commercial development. Our relationship with BG quickly developed into extraordinarily sensitive management support for global evaluation and acquisition, including a briefing by ARI's Vello Kuuskraa directly to CEO Mr. Frank Chapman.

ARI conducted a comprehensive global screening of all significant basins and CBM investment opportunities for BG Group. This included entry strategies and scoping out what a CBM business unit would look like (staff, management). ARI also evaluated the diverse strategies of global CBM operators. We then conducted a rigorous geologic and economic ranking of global CBM opportunities. Our study ranked Australia near the top of the list of preferred countries. ARI went on to evaluate all of the CBM operators in Australia in detail, with Vello Kuuskraa traveling to the country several times to assess lease quality and NAV. We provided key support for BG's acquisition of QGC for A\$5.2 billion in 2008-9, as well as its unsuccessful bid for Origin Energy.

**Private Client: CBM Training and Support: Global.** Client had no prior corporate CBM experience. During 2009-10 ARI was engaged to conduct multiple comprehensive CBM training programs for staff in domestic and international locations. This included formal training on CBM technology and lessons learned, as well as field visits to production areas and service company facilities. ARI also helped to design and provide on-site supervision of client's CBM test wells in international locations. We provided CBM data packages on other countries/basins which remain confidential at this time.

**Shell: CBM Strategy and Assessments: China/Indonesia.** During 2006 and 2007 ARI supported Shell on international coalbed methane strategy and assessment. At the time Shell did not have corporate experience producing or testing CBM. ARI's work began with a project on CBM "Lessons Learned and Corporate Strategy" for Shell Houston. ARI next evaluated CBM opportunities in China including the Ordos Basin, where Shell later leased its first-ever upstream CBM exploration block. Finally, ARI supported Shell on evaluation of CBM resources and potential entry strategies in Indonesia. ARI's Scott Stevens accompanied Shell management on several visits to China and Indonesia under these projects to meet with the government and potential corporate partners.



**Phillips Petroleum: CBM Training and Support: Global.** Conoco and Phillips already had significant CBM production in the San Juan Basin, United States. Nevertheless, lacking exploration and global CBM experience, Phillips engaged ARI during 1998 to 2002 to conduct CBM training for their staff in Houston, Calgary, and China. ARI evaluated numerous CBM prospects in the USA, Canada and China, helping to support Phillip's acquisition of the Shouyang and Qinnan PSC's in the Qinshui Basin (later farmed out to Far East Energy and Green Dragon Gas, respectively). ARI also provided well-site training and supervised gas content and hydraulic fracturing operations at seven CBM test wells at COP's Hedong PSC in the Ordos Basin.

**Chevron: CBM Training and Support: Global.** During the 1990's both Chevron and Texaco already had small-scale CBM production in the United States. Nevertheless, Texaco engaged ARI during 1994 to 2000 to conduct advanced training on CBM technology and to assist with their global CBM exploration evaluations. For Texaco, ARI evaluated CBM opportunities in Australia, China, Colombia, and Poland, traveling with Texaco staff to these locations to meet with government and company officials. We also helped to train field staff and supervised Texaco's CBM production pilot tests in China and Poland. ,

**Iscor Mining: Geologic and Structural Model: Botswana.** ARI assisted Iscor in developing a geologic and structural model to aid in the selection of wellsites for their CBM acreage in Botswana. The geologic analysis entailed the integration of satellite imagery data, aeromagnetic data, and corehole information. As part of this effort, we found two potential joint venture partners to develop the project with Iscor.

**Ingwe: Gas Content Testing: South Africa.** Provided on-site geologic support and gas desorption testing for two CBM coreholes drilled by Ingwe in the Waterberg basin. The work included calculating lost gas, measuring desorbed gas volumes, and determining residual gas volumes. Laboratory studies on all coal samples were conducted for vitrinite reflectance, proximate/ultimate analysis, and maceral composition. Several samples were selected for isotherm analysis and multi-component isotherms were run.

**ANGLO-COAL, Geologic and Engineering Consulting: South Africa.** ARI provided well testing and analysis services, reservoir simulation, and drilling and completion design for ANGLO's CBM project in the Waterberg basin. For the well testing, we designed the test procedures, procured the required equipment, and trained a local company in the execution of the tests. Using the permeability and other reservoir data gathered through well testing in conjunction with gas content and other data, we performed a full-field reservoir simulation to predict CBM recoveries from the field. The production streams generated through the reservoir simulation study served as the basis for economic and financial modeling of an anticipated full-field development. As part of this work, we also provided a technical assessment of the gas content and isotherm work completed and provided recommendations on how to improve their reporting. We also assisted in the design of the pilot project including cementing, hydraulic stimulation and production operations.

**Nata Energy Corp.: CBM Consulting: Botswana.** Performed a resource assessment and reservoir simulation study of Nata Energy's lease holdings in Botswana. Included in the evaluation was an economic analysis of field development.

**MCN Oil and Gas, CBM Feasibility Study: Southern Africa Region.** MCN Oil and Gas, a subsidiary of one of the largest natural gas utilities in the U.S., engaged ARI to identify high potential CBM projects in



Botswana, South Africa, and Zimbabwe. The work included geologic and engineering studies of the major coalfields, performing reservoir simulations to predict CBM reserves and recoveries, developing financial models to compare the different opportunities, and assisting them in finding local partners.

**Afpenn Exploration: CBM Geologic and Engineering Consultant: Zimbabwe.** For Afpenn Exploration, we provided on-site geologic support and gas content testing for 10 corewells drilled in the Lupane, Lubimbi, and Chiredzi areas. This work dates back to 1990 and represents the first attempts to quantify the CBM resources in Southern Africa.

**Shell International Exploration and Production; CBM Evaluation: South African Region.** Performed country evaluations of the CBM potential of Botswana and South Africa. Work included estimating gas in place, establishing production type curves for individual coal basins, preliminary economics, and market assessments.

**U.S. Trade and Development Agency: CBM Feasibility Study: Botswana.** ARI was awarded a \$635,000 grant to study the feasibility of developing CBM projects in Botswana. The study encompassed geologic and resource assessment, reservoir simulation, drilling, completion and stimulation design, surface facilities, market assessment, and an environmental effects analysis. The study provided the basis for an \$8.5 million loan facility from OPIC and the subsequent raising of an additional \$20 million in private equity.

**Zimbabwe Ministry of Transportation and Energy, CBM Confirmation Study.** ARI was awarded a contract by this Ministry to perform a CBM resource confirmation study of previously conducted exploration work in Zimbabwe. The scope of work includes visits to test wells, review of gas desorption work and permeability testing, determining gas-in-place resources for individual fields, commenting on the long term potential for commercial extraction, and assisting the Ministry in formulating policies and regulations to encourage the exploration and production of its CBM resources.