Potential for Shale Gas in Georgia:

Preliminary Study for Feasibility Analysis of Shale Gas Exploration in Georgia

Prepared for: AEAI under Grant Agreement #ECI-GA-R2-48
Georgia Energy Capacity Initiative
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By: World Experience for Georgia
www.weg.ge

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World Experience for Georgia (WEG) conducted a preliminary study for feasibility analysis of shale gas exploration in Georgia for USAID under the Georgia Energy Capacity Initiative Contract No. DOT-I-00-04-00022-00 (WEG Grant Agreement #ECI-GA-R2-48). This report was prepared for the benefit of USAID Georgia and provides the results of our study in fulfillment of our agreement. The overall goal of the project was to evaluate on a high level the existence and potential for development of shale gas resources in Georgia.

The authors' views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the United States Government.

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ABBREVIATIONS

GOGC – Georgian Oil and Gas Corporation

Ma – Million years ago

MoE – Ministry of Energy of Georgia

MPOW – Main phase of Oil window

MZOG – Main zone of oil generation

NAOG – National Agency for Oil and Gas

OGW – Oil & Gas window

OGZ – Oil-and-gas Zone

PSA – Production Sharing Agreement

Ro – Vitrinite reflectance in %

SG – Shale gas

TOC – Total organic carbon content of rocks in wt%.

GLOSSARY OF TERMS

Cretaceous – A geologic time period that spans from 60 Ma to 150 Ma in the Mesozoic Era.

Jurassic – A geologic time period that spans from 150 Ma to 200 Ma in the Mesozoic Era.

Kerogen –Kerogen is a mixture of organic chemical compounds that make up a portion of the organic matter in sedimentary rocks. It is insoluble in normal organic solvents because of the huge molecular weight (above 1,000 Daltons) of its compounds. The soluble portion is known as bitumen. When heated to the right temperatures in the Earth's crust, (oil window ca. 60°-160°C and gas window ca.150°->200°C, depending on how fast the source rock is heated) some types of kerogen transform into crude oil or natural gas. When kerogens are present in high concentration in rocks such as shale they may form source rocks. Shales rich in kerogens that have not been heated to a sufficient temperature to release their hydrocarbons may form oil shale deposits.

Liassic – the Early Jurassic epoch (in chronostratigraphy corresponding to the Lower Jurassic series) is the earliest of three epochs of the Jurassic period. The Early Jurassic starts immediately after the Triassic-Jurassic extinction event (199.6 Ma) and ends at the start of the Middle Jurassic (175.6 Ma). Rocks of this age are called Lias in Europe.

Maikop/Maikopian – a geological formation (series) of Late Oligocene to Early Miocene time (named after town of Maikop in North Caucasus) which is widely recognized throughout the Black Sea – Caspian region including Transcaucasus and characterized mostly by anaerobic marine depositional conditions. Rocks of Maikopian series are primarily composed of low permeability mudstones, and are considered as the source rocks of the most hydrocarbon deposits of the region.

Mesozoic – A geologic time era that spans 60 Ma to 250 Ma and includes the Triassic, Jurassic, and Cretaceous Periods.

Oil/Gas Window – a temperature and pressure dependent interval in the subsurface where oil and gas is generated from the source rocks. The oil window is often found in the 60-120 degree Celsius interval (approximately 2-4 km depth), while the corresponding gas window is found in the 100-200+ degree Celsius interval (3-6 km depth).

Shale – is a fine-grained, clastic, most common sedimentary rock composed of mud that is a mix of flakes of clay minerals and tiny fragments (silt-sized particles) of other minerals, especially quartz and calcite. Shale was and still is frequently referred to as slate in the post Soviet countries. Shale typically exhibits varying degrees of fissility breaking into thin layers, often splintery and usually parallel to the otherwise indistinguishable bedding plane because of parallel orientation of clay mineral flakes. The typical color is gray. Black shale results from the presence of greater than one percent carbonaceous material and indicates a reducing environment. Pyrite and

amorphous iron sulfide as well produce the black color in shale. Red, brown and green colors are indicative of ferric oxide (hematite - reds), iron hydroxide (goethite - browns and limonite - yellow), or micaceous minerals (chlorite, biotite and illite - greens) (*Glossary..., 1972; Blatt, Harvey and Tracy, 1996; McGraw…, 2003*).

Gas Shale – Organic-rich, fine-grained sedimentary rocks (shale to siltstone) containing a minimum of 0.5 wt % TOC. Gas shales may be thermally marginally mature (0.4-0.6% Ro) to mature (0.6-2.0% Ro) and contain biogenic to thermogenic methane. Gas is generated and stored *in-situ* in gas shales as both source bed (on organic matter) and free gas (in fractures and pores). Due to low permeability gas shales are source bed and reservoirs at the same time. They require (stimulation) to produce commercial quantities of gas (*Cardott, 2004*).

Source Bed, Source Rock – Over geologic time organic matter was buried in fine-grained sediments deposited in the various marine environments and to a less extent on upland areas from the erosion of mountainous areas. Eventually sediments were lithified (turned into rock) due to the pressure and heat created from the weight of overburden sediments. During lithification, the organic matter decomposed and was chemically altered to form hydrocarbons that through destructive distillation form crude oil and eventually natural gas. These sedimentary rocks become the **source beds/rocks** for petroleum resources within a region.

EXECUTIVE SUMMARY

Georgia is an oil and gas transit Country with limited fossil fuel resources. The primary gas supply to Georgia comes from transit fees from the South Caucasian Pipeline and gas Russia-to-Armenia transit over North-South natural gas pipeline supplemented by purchases from Azerbaijan and less from Russia. Domestic natural gas supply is highly important to energy independence, security and sustainability of Georgia. An exciting new oil and gas exploration frontier of the 21st Century - Shale Gas can be a chance for Georgia to drastically improve its energy security standing.

World Experience for Georgia (WEG) has applied for a grant to conduct a Preliminary Study for Feasibility Analysis of Shale Gas Exploration in Georgia for USAID under the Georgia Energy Capacity Initiative Grant program conducted by AEAI. The application was considered by AEAI and contract No. DOT-I-00-04-00022-00 (WEG Grant Agreement #ECI-GA-R2-48) was awarded. This report was prepared for the benefit of USAID Georgia and provides the results of our study in fulfillment of our agreement. The overall goal of the project was to evaluate on a high level the existence and potential for development of shale gas resources in Georgia.

The Government of Georgia has decided to study the prospects of developing shale gas production in the country. The principle objectives for developing shale gas are:

1. Increase energy security and sustainability of Georgia in long term,
2. Reduce the energy costs to Georgian population and economy,
3. Achieve maximum economic benefits from developing the indigenous mineral resource in Georgia

World Experience for Georgia (WEG) has conducted a preliminary feasibility analysis of shale gas exploration in Georgia. The study identified four primary candidate Gas Shale formations in Georgia:

a. Upper Miocene (Sarmatian)
b. Oligocene-Lower Miocene (Maikopian)
c. Middle Jurassic (Aalenian-Bathonian)
d. Lower Jurassic (Liassic)

These prospective Gas Shale formations are geographically located both within current Oil and Gas License Blocks as well as outside, on relatively less explored territories. They vary in their geographic spread as well as depths, thickness and the level of knowledge of their properties.

Although there have been numerous gas shows recorded from these formations, there is insufficient information to assess the gas in place and economic viability of its development. Very rough estimates of total potentially gas bearing shales indicate that in case of success the potential gas resource can be comparable to that of some most productive shale gas plays in the USA.

WEG classified the potential of Georgian Gas Shales as considerable with additional research required to prove gas resources. Further research, geological and reservoir data acquisition and analysis are needed to confirm the technical recoverable potential of gas shales. In addition market regulatory and infrastructure reviews are needed in order to verify economic viability of developing Shale Gas in Georgia.

Table 1 below compares the known properties of the four formations in Georgia.

Table 1. Comparative Table of Identified Potential Gas Shale Formations in Georgia

Shale Formation	Depth min/max	Thickness min/max	Maturity	Distribution	Tectonics	Lithology	Gas & Oil Shows	Level of knowledge
Upper Miocene (Sarmatian)	0/3,000	300/3,000	matured	Zonal in: Kartli and South Kakheti, Guria and Abkhazeti-Samegrelo, OGZs; local in Rioni and Near-Tbilisi OGZs	Low	sandy-clay sediments with interlayers of conglomerates and oolithic limestones	Oil shows	Intermediate
Oligocene-Lower Miocene (Maikopian)	0/>5,000	700/2,500	matured	Regional	Intermediate	clays (shales) and sandy-clays sediments	Oil & Gas shows	Good
Middle Jurassic Aalenian-Bathonian	0/>9,000	400/1,300	matured	Regional	Tectonized with vertical and overturned folding, overthrusts bedding and thrust faults	alternation of shales and sandstones	Oil	Poor- intermediate
Lower Jurassic (Liassic)	0/>10,000	200/1,500	matured-over-matured	Regional	Same as above but more tectonized	shales and slates with interlayers of sandstones and rear interlayers of limestones	Oil shows, bitumen	Poor-intermediate

Notes :

1. The Table contains only those identified shale formations with considerable areal extent and thicknesses allowing to consider them as primary targets for feasibility study.
2. Maturity (not to mix with oil maturity) implies the degree of diagenesis undergone by formations with respect being favorable for the Natural gas generation.
3. The Tectonics is a cumulative magnitude (range) of general folding, faulting affecting spatial traceability of the formation.
4. Because of technical and other reasons gas shows have not always been documented during the drilling process.
5. The Level of Knowledge implies accumulated set of information about general geological features like lithology, mineralogy, petro-mechanics, in situ pressures, etc.)

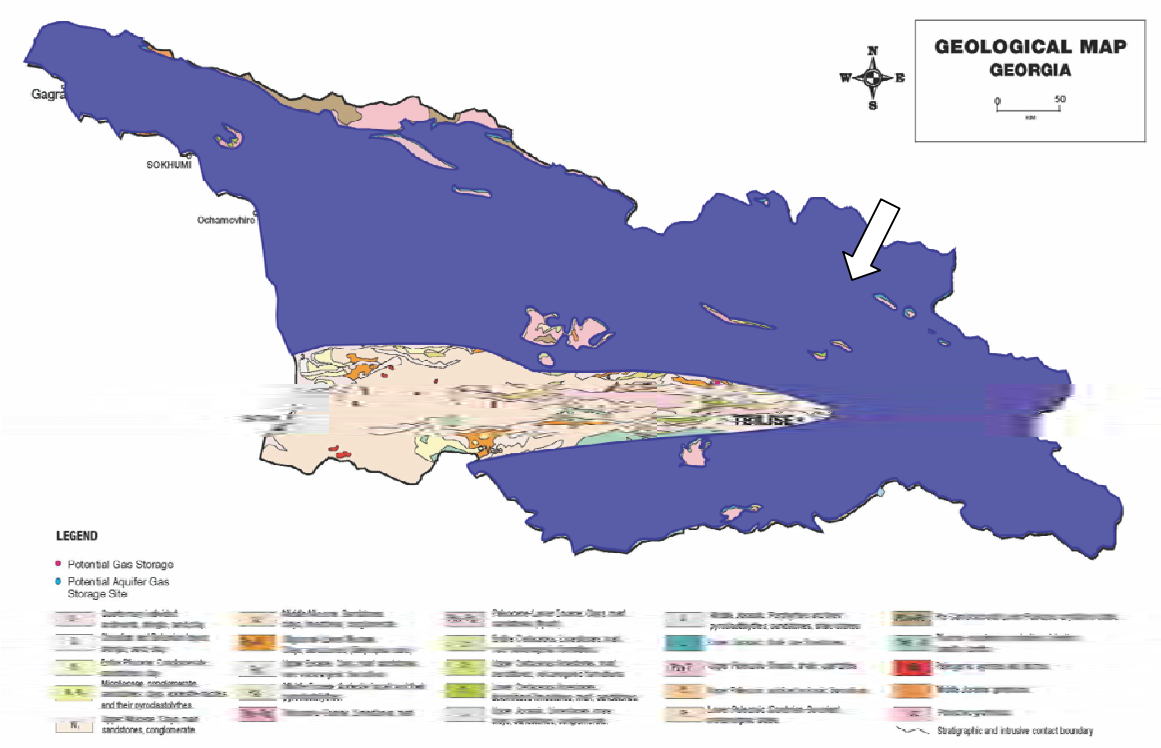

Figure 1. Geologic Map of Georgia Showing **Liassic formations.**

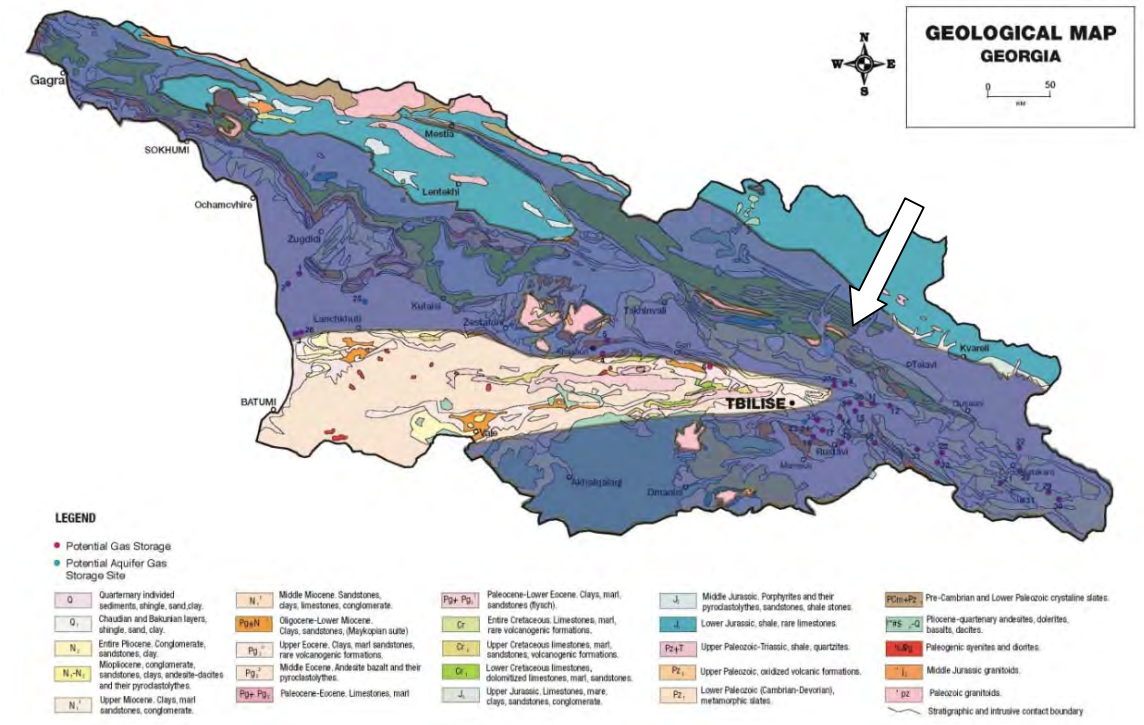

Figure 2. Geologic Map of Georgia Showing Areal Distribution of **Middle Jurassic** Formations.

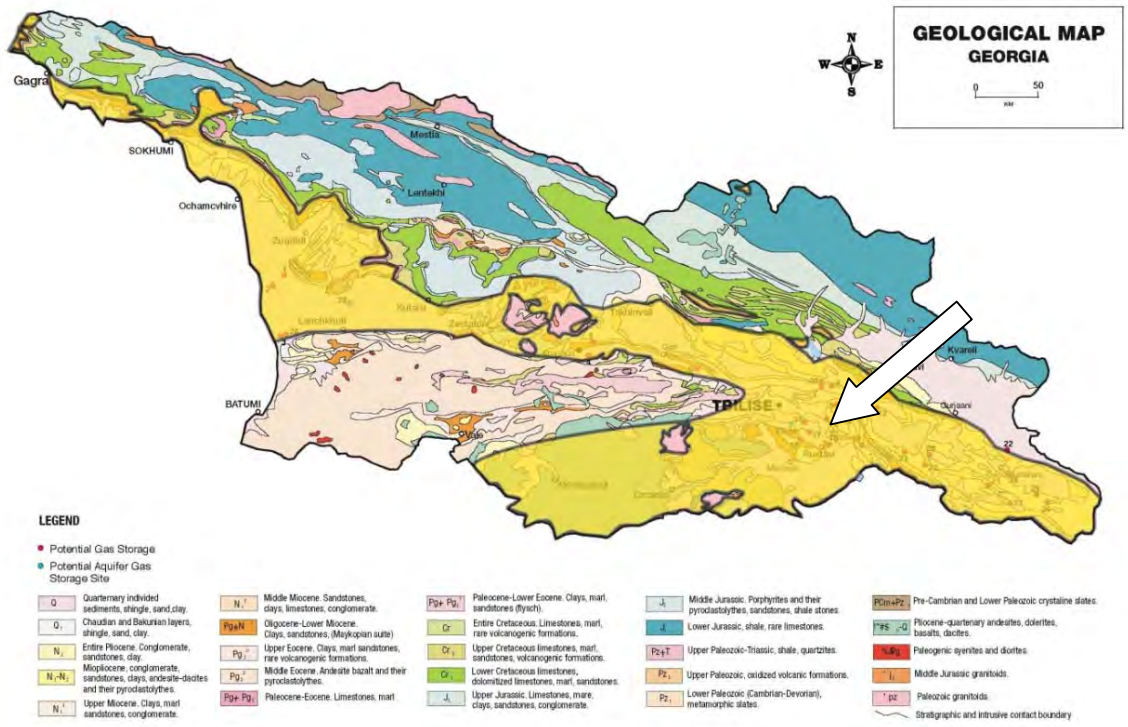

Figure 3 Geologic Map of Georgia Showing Areal Distribution of **Maikopian Series**

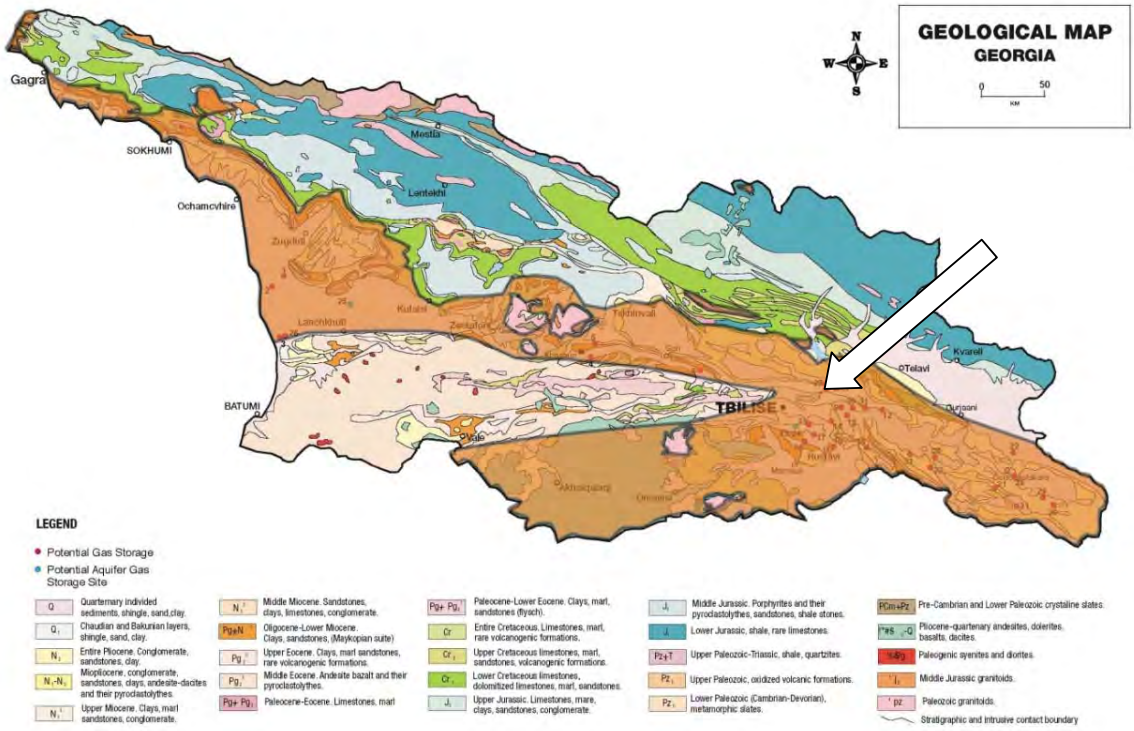

Figure 4. Geological Map of the **Upper Miocene (Sarmatian)** Formations.

Main Conclusions

Our Study has lead to the following main conclusions:

1. The capacity of Georgian sedimentary section to generate hydrocarbons is apparent from the occurrence of oil and gas fields, subsurface oil and gas shows, surface oil seeps, and analyses of organic matter from potential source rocks.
2. The primary candidate Gas Shale formations in Georgia are:
    a. Upper Miocene (Sarmatian)
    b. Oligocene-Lower Miocene (Maikopian)
    c. Middle Jurassic Aalenian-Bathonia-age shale sediments
    d. Lower Jurassic (Liassic)

    These sediments are present at varying depths over the northern and eastern one-third of Georgia.
3. The Sarmatian, Maikopian, and Liassic are known to be kerogen rich from surface oil seeps and oil and gas shows in wells. The Aalenian-Bathonian-age shale sediments show evidence of oil and gas in well logs. The thermal maturity within these formations tends toward oil versus natural gas and is favorable for shale gas.
4. The resource potential of Georgian Shale Gas can classified as considerable and are adequate to recommend implementing a Discovery Stage I assessment of Shale Gas in Georgia.
5. There is a host of geology information accumulated in different times at different institutions that needs to be consolidated and digitized for narrowing the range of shale gas exploration.
6. Numerous gas shows reported by various license block owners and from earlier periods, indicate a high probability of gas presence in these shale formations. As in many cases the main concern is the potential scale and the cost of its production.
7. Georgia is located in a gas rich neighborhood and there is no liquid gas market for shale gas. A wise long term marketing and promotion strategy will be needed for domestic gas to successfully compete with the traditional gas from neighboring countries on internal, regional and potentially international markets.
8. There is insufficient motivation for license block owners to develop traditional or non-traditional shale gas exploration and production. Additional market incentives and/or regulatory support mechanism, access to gas pipelines and other means of motivation should be considered.
9. A comprehensive gas strategy needs to be developed along with shale gas exploration in order to guide the government actions for promotion of domestic gas resources.

Feasibility Study for Shale Gas Production in Georgia

Development of Shale Gas production is faced with the challenges posed by extraordinary exploration, drilling and production measures and required by this nontraditional resource and relatively high cost resulting in higher sensitivity to market conditions. Success in this task is related to successful resolution of a number of problems including:

- Identification and Characterization of Shale Gas Resources,
- Understanding of Prospective Reservoirs,
- Development of Drilling and Completion Strategy,
- Creation of Favorable Market and Regulatory Conditions,
- Infrastructure Development and Access,
- Environmental Compliance and safe water management.

In order to successfully address these challenges, a feasibility study is needed to identify the most practical options for developing shale gas production in Georgia including technical, economic, socio-political, legal and regulatory, environmental and infrastructure factors into consideration.

The specific objectives of the feasibility study shall include:

1. Verify the existence of commercially viable quantities of shale gas in Georgia,
2. Assess the resource of shale gas – estimate the quantity and its areal and geologic spread,
3. Estimate the possible costs and volumes of production under (at least) two different scenarios,
4. Assess the potential market for Georgian shale gas and recommend market strategy,
5. Evaluate gas infrastructure and its development needs,
6. Recommend to the government the optimal approach and action plan for developing the shale gas production and utilization in Georgia.

The study shall be targeted to identifying the prospects of sustainable and economically beneficial production of shale gas in Georgia. The results of Stage I studies should provide sufficient evidence for the government and existing or potential investors to make informed decisions on further actions and should provide sound common grounds for cooperation between them.

Having in mind the limited resources that can be available for research, the study, based on available information and expert knowledge is to be aimed at maximization of potential economic benefit to Georgia, versus academic interest. The study should prepare the grounds for Stage II actual development of Shale Gas Plays and stimulate investment from existing license block owners and new potential investors.

Scope of Work for Stage 1 Shale Gas Resource Development Study

The scope of work (SoW) for this study is specific to Stage I-Shale Gas Play Discovery work activities and also addresses the issues defining the feasibility of its development. The study is to be conducted in consecutive tasks leading to an assessment of the economic potential of Shale Gas development in Georgia. The specific Tasks to complete this study is as follows:

Task 1. Develop a Central & Unified Geological Data Base for Georgia Shale Gas Deposits

Task 2. Shale Gas Exploratory Geology Analysis with License Block Operators

As a result of these activities all available surface and subsurface geological data in Georgia pertaining to prospective gas shales will be collected, cataloged and inputted into a Geological GIS data base system, subsurface geological framework model of Georgia shall be developed and Shale Gas deposits identified, gaps in data needed to evaluate the resource potential of Shale Gas deposits will be determined.

Task 3. Geological Framework Model of Shale Gas in Georgia

The objective of this investigation is to develop, based on all collected data, a geological framework model showing the depth, thickness, and areal extent of identified Gas Shale formations for the various regions of Georgia. It should also include a characterization of the formations in terms of rock type, reservoir rock properties (mineralogy, TOC, petrophysics), and presence of oil and gas. Field exploration (sampling and lab analyses Average 5 samples per formation type) will be conducted as a part of this task.

Task 4. Gas Market, Regulatory and Infrastructure Review

The perspectives of Shale Gas drastically depend on the market conditions and all factors affecting the cost of production. The objective of this review is to assess the potential market for Georgian SG including domestic, regional and international perspectives, to assess the regulatory and legal framework for shale gas developers and to assess availability and adequateness of infrastructure and other conditions relevant to Shale Gas development in Georgia.

Tasks 5-6. Shale Gas Resource Screening and Ranking Analysis, Geophysical Surveys of Candidate Shale Gas Play Areas

The screening, ranking, and selection of candidate Shale Gas play, Define Candidate(s) Shale Gas Play Study Area, Perform Geophysical Survey and Analyze Results to prepare for exploratory drilling.

Task 7. Exploratory Test Drilling and Geological Data Analysis

The objective of this Task is to drill an exploratory test hole and collect geological data on one of the primary candidate Shale Gas plays. The goal of the test well(s) is to 1) determine oil and gas reserves, 2) design and optimize a reservoir drainage program, 3) resolve potential technical issues, such as hydraulic rock fracturing methods and equipment requirements.

Task 8. Shale Gas Action Plan

The objective of this task is, to develop the recommendations and plans for further actions for the Government of Georgia to facilitate investment in shale gas development in Georgia. The task consists of several subtasks: Stage 2: a. Shale Gas Drilling and reservoir Evaluation Program, b. Shale Gas Market Development Recommendations, c. Risk Management Plan.

The total estimated cost to complete this Stage I Shale Gas Feasibility Analysis is **$2.78M** and the estimated duration is **16 months**. Breakdown by tasks is given below:

Project Tasks	**Estimated Costs**
Task 1. *Unified Geological Data Base*	$200K
Task 2. License Block Geology Analysis	$250K
Task 3. Geological Framework Model	$130K
Task 4. Market, Regulatory & Infrastructure Review	$50K
Task 5. Shale Gas Screening and Ranking Analysis	$50K
Task 6. Geophysical Surveys – planning, supervision and analysis	$100K
Task 6. Geophysical Surveys Subcontractors	$250K
Task 7. Exploratory Test Hole Drilling planning, supervision and analysis	$200K
Task 7. Drilling and Geophysical Testing Subcontractors	$1.5M
Task 8. Develop A Stage 2 Program	$50K
Total Estimated Costs	**$2.78M**

There is insufficient information to assess the gas in place however the very rough estimates of total potential gas bearing shales allows to conclude that the potential gas resource in Georgia can be comparable to some most productive shales in the USA.