World Experience in Shale Oil & Gas Industry and prospects of its Development in Georgia

Results of Preliminary Study of Shale Gas and Shale Oil Perspectives in Georgia

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In 2010 USAID funded and supported by Georgian Government project of preliminary study of POTENTIAL FOR SHALE GAS IN GEORGIA was conducted By:

- World Experience for Georgia – WEG
- Experts from Georgian Universities, and
- Hydrodynamics Ltd., USA

Potential for Shale Gas in Georgia:
Preliminary Study for Feasibility Analysis of Shale Gas Exploration in Georgia

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USAID Contract No. DOT-I-00-04-00022-00

By: World Experience for Georgia
www.weg.ge

September, 2010
STRATEGY OF THE PROJECT

Gas Shales Identification Criteria
- USA and other countries’ experience;
- Identification of key parameters

Identification of Possible Gas Shales
- Study of Georgia’s sedimentary formations

Screening
- Identification of screening criteria
- Separate approach for East and West Georgia
MEETINGS AND CONSULTATIONS

- The Ministry of Energy
- National Agency of Oil and Gas
- Georgian Oil and Gas Corporation
- With all main licensee companies
- USAID Georgia
- Georgian Agency of Spatial Information
- Caucasian Institute of Mineral Resources
- Institute of Geology of the Academy of Sciences
- With individual experts
<table>
<thead>
<tr>
<th>Basin</th>
<th>Formation</th>
<th>Rock Type</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uinta</td>
<td>Green River</td>
<td>Dolomite</td>
<td>Eocene</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>Monterey</td>
<td>Shale (silica rich)</td>
<td>Miocene</td>
</tr>
<tr>
<td>Texas/Louisiana/Mississippi Salt</td>
<td>Haynesville</td>
<td>Black Shale (clay rich)</td>
<td>Jurassic</td>
</tr>
<tr>
<td>San Juan</td>
<td>Lewis</td>
<td>Shale</td>
<td>Cretaceous</td>
</tr>
<tr>
<td>Raton</td>
<td>Pierre</td>
<td>Black Shale (clay rich)</td>
<td>Cretaceous</td>
</tr>
<tr>
<td>Williston</td>
<td>Gammon</td>
<td>Shale</td>
<td>Cretaceous</td>
</tr>
<tr>
<td>Denver</td>
<td>Niobrara</td>
<td>Chalk (rich in organic material)</td>
<td>Cretaceous</td>
</tr>
<tr>
<td>Forth Worth</td>
<td>Barnett</td>
<td>Black Shale (clay rich)</td>
<td>Mississippian</td>
</tr>
<tr>
<td>Williston</td>
<td>Bakken</td>
<td>Shale with interbedded Dolomite</td>
<td>Devonian-Missippian</td>
</tr>
<tr>
<td>Anadarko</td>
<td>Woodford</td>
<td>Black Shale (clay rich)</td>
<td>Devonian-Missippian</td>
</tr>
<tr>
<td>Arkoma</td>
<td>Woodford</td>
<td>Black Shale (clay rich)</td>
<td>Devonian-Missippian</td>
</tr>
<tr>
<td>Illinois</td>
<td>New Albany</td>
<td>Black Shale (clay rich)</td>
<td>Devonian</td>
</tr>
<tr>
<td>Michigan</td>
<td>Antrim</td>
<td>Black Shale (clay rich)</td>
<td>Devonian</td>
</tr>
<tr>
<td>Appalachian</td>
<td>Cinnamon, Fredonia, Macellus</td>
<td>Shale (clay rich)</td>
<td>Devonian</td>
</tr>
</tbody>
</table>
SHALES ARE DIFFERENT

Modified from Hill and Nelson, 2000
DIFFERENT TYPES OF GAS SHALES
THE CRITERIA
What are Shale Gas and Shale Oil Deposits?

① Organic-Kerogen Rich Clastic Sediments
② Source rock for oil & gas deposits within a geologic basin
③ Unconventional Resource

① Low Permeability
② As a rule requires unique drilling and development technology
Gas Shale Definition

• Even in English there are numerous definitions of traditional shale – a sedimentary rock formed by the consolidation of mud, silt or clay and having the property of splitting into thin layers parallel to its bedding planes.

• In general, modern definitions of Gas Shales left aside mineralogy, degree of maturity and metamorphism and include only statements about sediment rocks with certain sizes of grain and states in general that Gas and Oil Shales are serve as a source and reservoir for the in situ generated hydrocarbons. Some definitions also mentioning kerogen type and permeability.

• Initially by many our experts it was assumed that Gas Shales and traditional shales are the same. Such approach left beyond the range of consideration very promising lithological formations constituting almost $\frac{3}{4}$ of formations which can be qualified as Gas and/or Oil Shales.
Diagenesis and Maturity of Oil Prone Source

Maturity
- Diagenesis
- Immature Methane Zone
- Oil Zone
- Wet Gas Zone
- Dry Gas Zone

MEGF
- Generation Intensity

Temperature (°C)
- Light Oil
- Heavy Oil
- Biogenic Methane
- Wet Gas
- Dry Gas

Modified after: IHRDC Image
Kerogen type

- All shale gas plays are in oil prone, marine “Type II” kerogen facies
- So called “gas prone” or coaly OM are not significant!

<table>
<thead>
<tr>
<th>Maceral</th>
<th>Kerogen Type</th>
<th>Original OM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alginite</td>
<td>I</td>
<td>Fresh-water algae</td>
</tr>
<tr>
<td>Exinite</td>
<td>II</td>
<td>Pollen, spores</td>
</tr>
<tr>
<td>Cutinite</td>
<td>II</td>
<td>Land-plant cuticle</td>
</tr>
<tr>
<td>Resinite</td>
<td>II</td>
<td>Land-plant resins</td>
</tr>
<tr>
<td>Liptinite</td>
<td>II</td>
<td>All land-plant lipids; marine algae</td>
</tr>
<tr>
<td>Vitrinite</td>
<td>III</td>
<td>Woody and cellulosic material from land plants</td>
</tr>
<tr>
<td>Inertinite</td>
<td>IV</td>
<td>Charcoal; highly oxidized or reworked material of any origin</td>
</tr>
</tbody>
</table>
Primarily Oil Bearing Sediments in Georgia
Occurrences of Gas and Oil shows in different formations of sedimentary complex of West and East Georgia

According to D. Papava by courtesy of FRONTERA
<table>
<thead>
<tr>
<th>#</th>
<th>Complex</th>
<th>Composition</th>
<th>Thickness (m)</th>
<th>Lithology</th>
<th>Area of distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lower Pliocene (Shiraki suite)</td>
<td>Terrigenous</td>
<td>up to 2500</td>
<td>Clays, sandstones, conglomerates</td>
<td>Zonal in South Kakhetian and local in Alazani-Agrichai OGZs</td>
</tr>
<tr>
<td>2</td>
<td>Upper Miocene</td>
<td>Terrigenous</td>
<td>1450-2250</td>
<td>Sandy-clay sediments with interlayers of conglomerates and oolithic limestones</td>
<td>Zonal in Kartli and South Kakhetian and local in Near-Tbilisi OGZs                                             +</td>
</tr>
<tr>
<td>3</td>
<td>Middle Miocene</td>
<td>Terrigenous</td>
<td>40-600</td>
<td>Clays (shales) with interlayers of sandstones</td>
<td>Zonal in Kartli and South Kakhetian OGZ; local in Near-Tbilisi OGZ                           +</td>
</tr>
<tr>
<td>4</td>
<td>Oligocene-Lower Miocene</td>
<td>Terrigenous</td>
<td>500-1500 and more</td>
<td>Clays (shales) and sandy-clays sediments</td>
<td>Regional (except Achara-Trialeti zone)                                                   +</td>
</tr>
<tr>
<td>5</td>
<td>Upper Eocene</td>
<td>Terrigenous</td>
<td>100-3000</td>
<td>Clays(?) and shales with interlayers of sandstones</td>
<td>Regional (except Achara-Trialeti zone)                                                 +</td>
</tr>
<tr>
<td>6</td>
<td>Middle Eocene</td>
<td>Volcanogenic</td>
<td>200-600</td>
<td>Volcanogenic-sedimentary rocks (tuffs, lavas etc.)</td>
<td>Zonal in Near-Tbilisi, Kartli and South Kakhetian OGZs;</td>
</tr>
<tr>
<td>7</td>
<td>Paleocene-Lower Eocene</td>
<td>Terrigenous</td>
<td>up to 3500-4000</td>
<td>Sandy-clay sediments with interlayers of limestones and marls</td>
<td>Regional</td>
</tr>
<tr>
<td>8</td>
<td>Turonian-Danian</td>
<td>Carboniferous</td>
<td>200-1200</td>
<td>Limestones and marls; lower occur volcanogenic rocks</td>
<td>Regional</td>
</tr>
<tr>
<td>9</td>
<td>Neokom-Aptian</td>
<td>Carboniferous</td>
<td>up to 1000-1500</td>
<td>Limestones, marls; locally interlayers of sandstones and volcanogenic rocks</td>
<td>Regional</td>
</tr>
<tr>
<td>10</td>
<td>Upper Jurassic</td>
<td>Terrigenous</td>
<td>500-1500 and more</td>
<td>Upper: speckled clays, sandstones; lower: sandy-clays with interlayers of coal-bearing rocks; lowest: volcanogenic rocks</td>
<td>Regional                                                                               +</td>
</tr>
<tr>
<td>11</td>
<td>Upper Bajocian-Batonian</td>
<td>Terrigenous</td>
<td>up to 1000</td>
<td>Alternation of shales and sandstones</td>
<td>Regional (?)                                                                          +</td>
</tr>
<tr>
<td>12</td>
<td>Liassic</td>
<td>Terrigenous</td>
<td>200-1200 maybe more</td>
<td>Shales with interlayers of sandstones and rear interlayers of limestones</td>
<td>Regional                                                                               +</td>
</tr>
</tbody>
</table>
## HYDROCARBONS BEARING FORMATIONS OF GEORGIA
### Western Georgia

<table>
<thead>
<tr>
<th>#</th>
<th>Complex</th>
<th>Composition</th>
<th>Thickness (m)</th>
<th>Lithology</th>
<th>Area of distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Meothian</td>
<td>Terrigenous</td>
<td>up to 1000</td>
<td>Conglomerates, clay with interlayers of sandstones</td>
<td>Zonal in Guria OGZ; local in Abkhazeti-Samegrelo and Rioni OGZ</td>
</tr>
<tr>
<td>2</td>
<td>Upper Miocene</td>
<td>Terrigenous</td>
<td>up to 2000-2500</td>
<td>Sandy-clay sediments</td>
<td>Zonal in Guria and Abkhazeti-Samegrelo OGZ; local in Rioni OGZ</td>
</tr>
<tr>
<td>3</td>
<td>Oligocene-Lower Miocene</td>
<td>Terrigenous</td>
<td>200-1900</td>
<td>Clays (shales) and sandy-clay sediments</td>
<td>Regional</td>
</tr>
<tr>
<td>4</td>
<td>Middle Eocene</td>
<td>Volcanogenic</td>
<td>1300-4000</td>
<td>Volcanogenic-sedimentary rocks (tuffs, tuff-aleurolites, andesites, basalts, marls etc.)</td>
<td>Zonal in Guria OGZ; and Achara-Imereti OGZ</td>
</tr>
<tr>
<td>5</td>
<td>Turonian-Danian</td>
<td>Carboniferous</td>
<td>200-1000</td>
<td>Fractured limestones and marls</td>
<td>Regional</td>
</tr>
<tr>
<td>6</td>
<td>Neokom-Aptian</td>
<td>Carboniferous</td>
<td>up to 1000-1200</td>
<td>Limestones, dolomitized limestones and dolomites</td>
<td>Regional</td>
</tr>
<tr>
<td>7</td>
<td>Upper Jurassic</td>
<td>Volcanogenic-Terrigenous</td>
<td>up to 2500</td>
<td>In upper part salt-bearing section; lower: sandy-clay sediments; lowest: volcanogenic rocks (albite basalts and dolerites)</td>
<td>Regional</td>
</tr>
<tr>
<td>8</td>
<td>Upper Bajocian-Batonic</td>
<td>Terrigenous</td>
<td>up to 1000</td>
<td>Alternation of shales and sandstones</td>
<td>Regional</td>
</tr>
<tr>
<td>9</td>
<td>Liassic</td>
<td>Terrigenous</td>
<td>up to 1000</td>
<td>shales with interlayers of sandstones and rear interlayers of limestones</td>
<td>Regional</td>
</tr>
</tbody>
</table>
Potential Shale Gas Formations of Georgia

Paleogene-Neogene

① Upper Miocene (Sarmatian)
② Oligocene-Lower Miocene (Maikopian Series)

Jurassic-Age

① Middle Jurassic (Aalenian-Bathonian)
② Lower Jurassic (Liassic)
<table>
<thead>
<tr>
<th>Shale Formation</th>
<th>Depth min/max</th>
<th>Thickness min/max</th>
<th>Maturity</th>
<th>Distribution</th>
<th>Tectonics</th>
<th>Lithology</th>
<th>Gas &amp; Oil Shows</th>
<th>Level of knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Miocene (Sarmatian)</td>
<td>0/3,000</td>
<td>300/3,000</td>
<td>matured</td>
<td>Zonal in: Kartli and South Kakheti, Guria and Abkhazeti-Samegrelo, OGZs; local in Rioni and Near-Tbilisi OGZs</td>
<td>Low</td>
<td>sandy-clay sediments with interlayers of conglomerates and oolithic limestones</td>
<td>Oil shows</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Oligocene-Lower Miocene (Maikopian)</td>
<td>0/&gt;5,000</td>
<td>700/2,500</td>
<td>matured</td>
<td>Regional</td>
<td>Intermediate</td>
<td>clays (shales) and sandy-clays sediments</td>
<td>Oil &amp; Gas shows</td>
<td>Good</td>
</tr>
<tr>
<td>Middle Jurassic Aalenian-Bathonian</td>
<td>0/&gt;9,000</td>
<td>400/1,300</td>
<td>matured</td>
<td>Regional</td>
<td>Tectonized with vertical and overturned folding, overthrusts bedding and thrust faults</td>
<td>alternation of shales and sandstones</td>
<td>Oil</td>
<td>Poor- intermediate</td>
</tr>
<tr>
<td>Lower Jurassic (Liassic)</td>
<td>0/&gt;10,000</td>
<td>200/1,500</td>
<td>matured-over-matured</td>
<td>Regional</td>
<td>Same as above but more tectonized</td>
<td>shales and slates with interlayers of sandstones and rear interlayers of limestones</td>
<td>Oil shows, bitumen</td>
<td>Poor-intermediate</td>
</tr>
</tbody>
</table>
According to the current Experience Shale gas and shale oil basins and formations that have very high clay content and/or have very high geologic complexity (e.g., thrusted and high stress) are assigned a high prospective area risk factor or as a rule, are excluded from the resource assessment.
1. Low perspective;
2. Perspective;
3. Uncertain perspectives;
4. Non-perspective.
Based on current knowledge on the Black Sea offshore geology we think that Georgian sector is quite promising from the unconventional hydrocarbons point of view. Particularly special attitude deserve Maikopian sequence (TOC ~1.8%) and Lower Cretaceous sediments (TOC ~1.9%) [Black Sea Azov Sea. Report #EB014, Simon Petroleum Technology, 1994]
OIL AND GAS LICENSE BLOCKS OF GEORGIA
CONCLUSIONS
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.

The primary candidate Gas Shale formations in Georgia are: i) Upper Miocene (Sarmatian); ii) Oligocene-Lower Miocene (Maikopian); iii) Middle Jurassic Aalenian-Bathonian-age shale sediments, and iv) Lower Jurassic (Liassic).

These sediments are present at varying depths over the northern and eastern one-third of Georgia.

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.
The resource potential of Georgian Shale Gas and Shale Oil can be classified as considerable and are adequate to recommend implementing further big scale assessment of Shale Gas and Shale Oil in Georgia.

Numerous gas and oil shows reported by various license block owners and from earlier periods, indicate a high probability of gas and/or oil presence in these shale formations. As in many cases the main concern is the potential scale and the cost of its production.

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.

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.
Development of Shale Gas Is Problematic

RESOURCE ACCESSMENT DIFFICULT

MAJOR DATA ISSUES

① Little to no Data
   ① Typically Overlooked by Oil & Gas Companies
   ② Maybe Only Recorded as a Gas Show on a Log

② Data Not Easily Accessible
   ① Held By Multiple Agencies
   ② Held by License Block Operators

③ Data Never Been Analyzed for Shale Gas Development
   ① Economic Incentive Not Adequate in Lieu of Trading Oil & Gas Plays

ADVANCE TECHNOLOGY NECESSARY TO ACCESS & DEVELOP RESOURCE

① Complex Exploratory Drilling & Development
   ① Horizontal Drilling
   ② Well Depths
   ③ Over Pressured Environment

② Unique & Proprietary Logging Analysis Tools & Mythology
   ① Special Logging Tools
   ② Complex Hydro Fracturing Required
General Approach to Development

- Develop the play concept, lease the core
- Partner up to drill a science or a proof-of-concept well
  - demonstrate presence of mobile gas
  - magnitude of gas in place resource
  - some minimum level of deliverability after frac
- Development will require horizontal drlg and fracing. Gets $$$$$ quickly. Few of these plays work on a low cost, vertical well basis.
Develop a Unified Geological Data Base
- GIS System of Well Logs (only 3,000 well logs)
- Digital 3D Maps of Potential SG Formations

Develop a SG Resource Analysis Program with Licensees
- Detailed Prospect Mapping by Blocks
- Prepare Prospect Development Plan by Blocks

Pilot Exploratory Drilling & Test Program
- Drill Pilot Exploratory Well
- Produce Gas or Oil from Pilot Well

Design & Implement SG Program
- Define Prospects
- Develop Funding Program
- Implement Program

Approach to Shale Gas & Shale Oil In Georgia
FURTHER STEPS

Successful development of Shale Gas and Shale Oil in Georgia will depend on resolving of following issues:

• Identification and description of Shale Gas and Shale Oil resources;
• Compiling of 3D digital map of possible Gas and Oil shales
• Modeling and study of Gas bearing reservoirs (formations)
• Identification of well drilling and well completion technologies;
• Price and volume of extracted gas
• Elaboration of regulations
• Environmental issues: emissions, waste and water management, land use etc.
Thank you very much! and
Questions?