

WCSB

RESOURCE PLAY ATLAS

**WESTERN CANADA SEDIMENTARY BASIN
GEOCHEMICAL DATABASE AND PETROLEUM
SYSTEM MAPPING PROJECT**



GEO MARK RESEARCH, LTD.

A Proposal



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EXECUTIVE SUMMARY

GeoMark Research is commencing a multi-year effort to assess the commercial potential of every exploration play in the Western Canada Sedimentary Basin (WCSB). This will be accomplished by integrating and interpreting the contents of a comprehensive, evolving database of geochemical and reservoir engineering analyses (Figure 1), and constructing GIS map-based assessments of hydrocarbon resource, oil families, hydrocarbon character, phase behavior and thermal histories of each evaluated formation (Figure 2).

GeoMark's WCSB Geochemical Database includes all publically available data, along with a large collection of proprietary results. Over the next three (3) years GeoMark will increase the size of this database by analyzing additional samples obtained by GeoMark, or contributed by participants. The final result of this study will be interpreted maps of source rock potential integrated with maps of oil and gas fluid characterization and regional phase behavior trends. Combined, these maps and interpretative commentary will comprise a digital WCSB Resource Play Atlas and provide a geochemical characterization and quantification of oil and gas potential in each horizon.

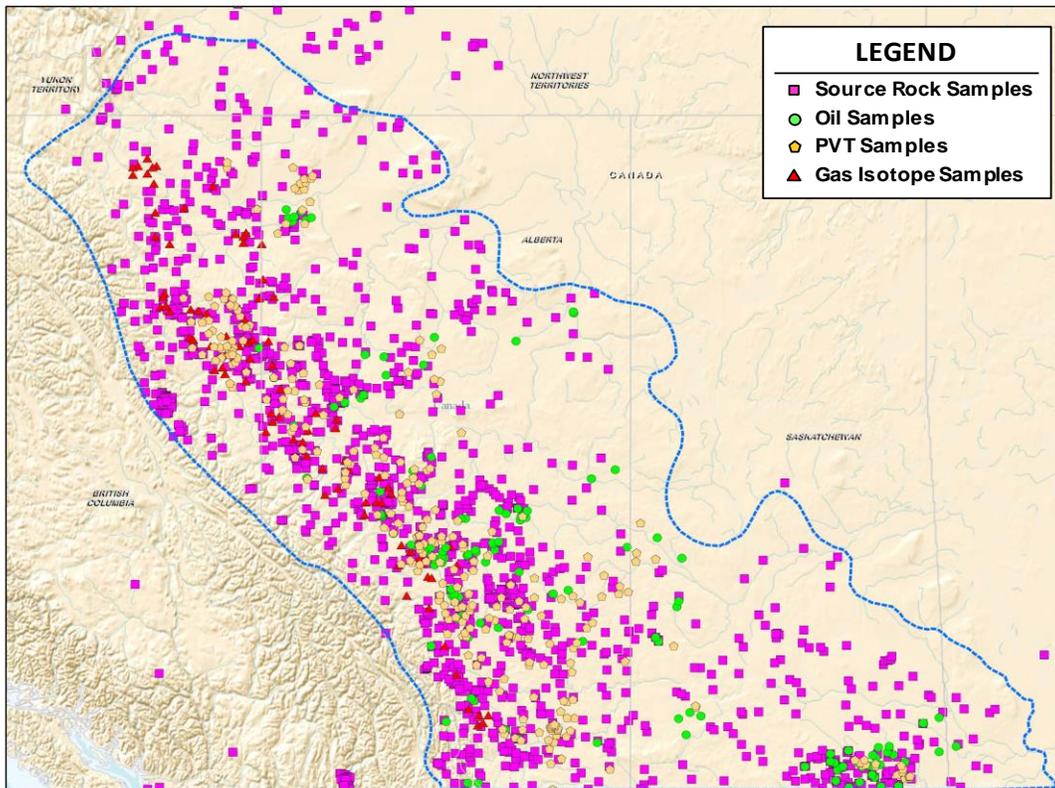


Figure 1. Geographical limits of the Western Canada Sedimentary Basin and the geochemical samples currently in the GeoMark WCSB-Database.

This proposal describes the WCSB Geochemical Database and the methods used to map and assess exploration potential. The Atlas will require three years to complete. Participation in this program is CAD \$95,000.00 per year, with a three (3) year minimum. The bulk of the analytical results will be released at contract signing, with the remaining data and the interpretive reports being released every six months.

INTRODUCTION

The WCSB is one of the key regions in North America for both unconventional and conventional resource opportunities, with the term *resource play* used in the broadest sense. In the next several years the industry has an opportunity, particularly in the current price environment, to evaluate each horizon in the WCSB to further assess the unit's potential as a resource play. The stage will then be set for accelerated exploration and development and application of new technologies to more conventional plays when commodity prices stabilize and improve.

FORMATION	AGE	GROUP	LITHOLOGY
BELLY RIVER	UPPER CRETACEOUS		SANDSTONE
CARDIUM	UPPER CRETACEOUS		SANDSTONE
SECOND WHITE SPECKS	UPPER CRETACEOUS	COLORADO	SHALE
DOE CREEK	UPPER CRETACEOUS	KASKAPAU	SANDSTONE
VIKING	LOWER CRETACEOUS	COLORADO	SANDSTONE
MANNVILLE BLAIRMORE	LOWER CRETACEOUS	MANNVILLE	SANDSTONE
MANNVILLE BUICK	LOWER CRETACEOUS	MANNVILLE	SANDSTONE
MANNVILLE SPARKY	LOWER CRETACEOUS	MANNVILLE	SANDSTONE
MANNVILLE MOULTON	LOWER CRETACEOUS	MANNVILLE	SANDSTONE
MANNVILLE GLAUCONITE	LOWER CRETACEOUS	MANNVILLE	SANDSTONE
MANNVILLE OSTRACOD	LOWER CRETACEOUS	MANNVILLE	SANDSTONE
MANNVILLE ELLERSLIE	LOWER CRETACEOUS	MANNVILLE	SANDSTONE
MANNVILLE BLUESKY	LOWER CRETACEOUS	MANNVILLE	SANDSTONE
MANNVILLE SUNBURST	LOWER CRETACEOUS	MANNVILLE	SANDSTONE
MANNVILLE GETHERING	LOWER CRETACEOUS	MANNVILLE	SANDSTONE
MANNVILLE TABER	LOWER CRETACEOUS	MANNVILLE	SANDSTONE
ROCK CREEK	UPPER CRETACEOUS		SANDSTONE
NIKANASSIN	LOWER CRETACEOUS		CARBONATE
ELLIS SAWTOOTH	MIDDLE JURASSIC		SANDSTONE
SHAUNVAVON	MIDDLE JURASSIC		CARBONATE
POKER CHIP	LOWER JURASSIC	FERNIE	SHALE
NORDEGG	LOWER JURASSIC	FERNIE	CARBONATE
BALDONNEL	UPPER TRIASSIC	SCHOOLER CREEK	CARBONATE
CHARLIE LAKE	UPPER TRIASSIC	SCHOOLER CREEK	EVAPORITE
HALFWAY	UPPER TRIASSIC		SANDSTONE
DOIG	TRIASSIC		SHALE
MONTNEY	MIDDLE TRIASSIC		SHALE
BELLOY	PERMIAN		CARBONATE
DEBOLT	MISSISSIPPIAN		CARBONATE
ELKTON	MISSISSIPPIAN	TURNER VALLEY	CARBONATE
PEKISKO	MISSISSIPPIAN	RUNDLE	CARBONATE
BANFF	MISSISSIPPIAN		SHALE
EXSHAW	MISSISSIPPIAN		SHALE
FROBISHER	MISSISSIPPIAN		CARBONATE
TURNER VALLEY	MISSISSIPPIAN		CARBONATE
MIDALE	LOWER MISSISSIPPIAN		CARBONATE
MIDDLE BAKKEN	LOWER MISSISSIPPIAN		SANDSTONE
MISSION CANYON	LOWER MISSISSIPPIAN	MADISON	CARBONATE
BAKKEN	UPPER DEVONIAN		SHALE
BEAVERHILL LAKE	UPPER DEVONIAN		CARBONATE
WABAMUN	UPPER DEVONIAN		SANDSTONE
DUVERNAY	UPPER DEVONIAN	WOODBEND	SHALE
NISKU	UPPER DEVONIAN		CARBONATE
IRETON	UPPER DEVONIAN	WOODBEND	CARBONATE
LEDUC	UPPER DEVONIAN	WOODBEND	CARBONATE
DUVERNAY	UPPER DEVONIAN	WOODBEND	SHALE
MUSKEG	UPPER DEVONIAN		EVAPORITE
SWAN HILLS	UPPER DEVONIAN	BEAVERHILL LAKE	CARBONATE
SLAVE POINT	UPPER DEVONIAN		CARBONATE
GILWOOD	MIDDLE DEVONIAN		SANDSTONE
KEG RIVER	MIDDLE DEVONIAN		CARBONATE
GRANITE WASH	LOWER DEVONIAN		SANDSTONE

Figure 2. Stratigraphic units to be evaluated. Nomenclature and lithologies may vary across the provinces.

The WCSB benefits from a very large number of unconventional and more conventional targets. These include organic-rich source facies, as well as non-source, reservoir facies. Based on current North American successes, both of these facies are excellent candidates for horizontal drilling and multi-stage frac completions. Therefore, the study will evaluate resource plays that are both source and reservoir, (e.g. the Devonian Duvernay) and hybrid source-reservoir plays such as the Alberta Bakken. Additionally, more conventional plays (e.g., reservoirs within the Cretaceous Viking Fm. and Mannville Group) will be examined to determine hydrocarbon source, oil maturity and quality variations, and probable migration direction and extent within each studied petroleum system.

Geochemical analysis of source rocks, oils, and gases has proven to be a necessary, primary technique for assessing and quantifying the resource potential of various established plays. Accordingly, GeoMark has evaluated many of the major US resource plays from 2011-present through similar consortia (e.g., Bakken, Eagle Ford, Greenhorn, Marcellus, Mowry, Niobrara, Phosphoria, Utica, Wolfcamp/Cline and Woodford). We will continue to refine and adapt our interpretive approach as we work with member companies to evaluate the WCSB.

Petroleum systems from the Devonian to Upper Cretaceous across the provinces of Alberta, British Columbia and Saskatchewan will be evaluated for inclusion in the GeoMark WCSB Resource Play Atlas. As with previous GeoMark North American resource potential studies, the integration of petroleum geology and applied geochemistry will allow an understanding of petroleum generation, timing, volumes generated, and extent and probable direction of migration. Additionally, through PVT and thermal maturity analyses, we will predict probable hydrocarbon phase(s) and critical production parameters such as reservoir pressure-bubble/dew point pressure relationships.

Canadian and U.S. shale oil and shale gas production has increased dramatically in the last five years. Horizontal drilling and multi-stage hydraulic fracturing have resulted in significant productivity improvements from plays such as the Cardium, Beaverhill Lake carbonates and Viking formations. The liquids-rich area of the Montney in British Columbia was the focus of multiple talks at recent technical conferences.

Industry activity and published studies have demonstrated that numerous organic-rich units in Alberta, British Columbia and portions of Saskatchewan are productive or potentially productive commercial oil or gas resource plays. No fewer than 12 different formations from petroleum systems of Devonian to Cretaceous age have sufficient organic content and quality to consider as a potential resource target (Figure 2), while at least 30 formations have potential as non-source reservoir units.

In this current period of lower and more volatile oil and gas prices, there is opportunity to complete applied research to assess and rank each of these productive and potentially productive units, particularly with respect to source thermal maturity, predicted hydrocarbon phase and insight into possible migration to conventional reservoirs. While integration of source rock and produced oil and gas data has advanced in recent years, and resulted in numerous GSC and other literature publications, current North American resource plays have highlighted the need to also consider phase behavior – via PVT analyses – to maximize production and high-grade existing and future land positions.

This Atlas will utilize GeoMark's extensive North American Oil, Gas, Source Rock and PVT Databases. All of these data will be used in the study, and new analytical results (source and reservoir rock, oil, gas and PVT) will be added during the course of the project. Each of these petroleum system studies will result in an expanding GIS database of geochemical data that can be used to interpret future results. It is important to realize that while appropriate public data (e.g., GSC studies and data provided by operators to regulatory agencies) will be included, the majority of the data are proprietary to GeoMark. This is especially true for oil and rock/rock extract data.

DELIVERABLES AND PRESENTATION OF RESULTS

The WCSB Geochemical Database is divided into the following modules. The size of each of the current datasets is shown below, along with the anticipated size of each module in three years.

Module	Sample Count	
	Current	Year Three
Source Rock Analyses	35,000	37,000
Oil Analyses	162	500+
PVT Reports	394	850+
Gas Analyses (composition only)	6,000+	10,000+
Gas Analyses (carbon isotope)	112	300+

Additional analytical work will continue steadily over the next three years. New data will be released to the database as the analyses are completed. Interpreted formation maps will be released at six month intervals as specific updates are available. A digital WCSB Resource Play Atlas of all maps and interpretative commentary generated during the course of the project will be the final deliverable.

Source Rock Analyses

The first step in the evaluation of each formation will be to map source-rock potential. A GeoMark-developed, eight-step process is being employed to fully assess the source potential of each unit. These maps are built in ArcGIS, giving participating companies the ability to expand the database with new or proprietary data. The following maps will be constructed and evaluated for each unit.

- Measured present-day organic richness (TOC_{pd});
- Maximum measured present-day organic richness (TOC_{max});
- Calculated present-day hydrogen index, S₂/TOC*100 (HI_{pd});
- Calculated present-day production index S₁/(S₁ + S₂) (PI_{pd});
- Thermal maturity: Vitrinite reflectance equivalent calculated from T_{max} (CVR).
Measured R_o values will be used when available and appropriate;
- Calculated original (depositional) organic richness (TOC_o);
- TOC consumed during hydrocarbon generation, TOC_o-TOC_{pd}, (TOC_{gen});
- Calculated volumes of generated hydrocarbons.

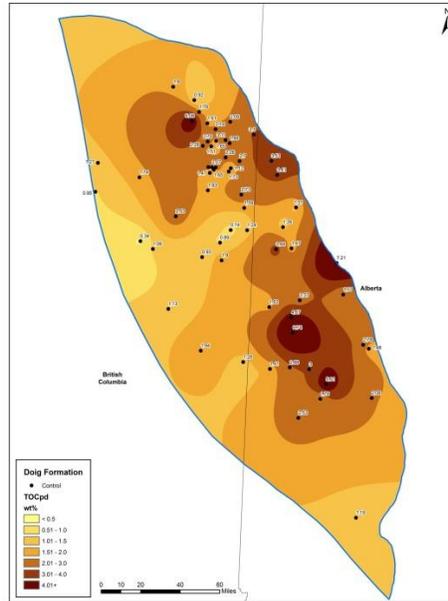


Figure 3. Present day TOC levels of the Doig Formation.

Figure 3 shows the present day TOC map for the Doig Formation. This map shows that the entire Doig interval is organic rich, but the downdip portion has lost TOC due to hydrocarbon generation. These types of maps identify regions that have generated hydrocarbons, predict the nature of the hydrocarbons (oil, gas, or condensate), and provide information for estimates of commercial viability.

Oil & Gas Analyses

GeoMark will provide data from its standard analytical program (presented below) for each of the oil and gas samples in the database (Figure 1). Multiple oil families (and by inference multiple source units) have been identified in the WCSB, and numerous potential source units have been reported as possible unconventional targets (Figure 2). It is important to establish which of these units will be viable opportunities and to determine where they have the greatest potential.

In non-source units we will determine which source unit(s) generated the migrated oil, and map the nature and character of the migrated oil.

- API Gravity
- % Sulfur
- Nickel/Vanadium concentration
- C15+ vs. <C15 hydrocarbons
- Deasphalting
- Liquid Chromatography (%Saturate, %Aromatic, %NSO & %Asphaltenes)
- Capillary GC of Whole Crudes
- Stable Carbon Isotopes for both Saturate and Aromatic Hydrocarbon Fractions
- GC/MS of branched/cyclic fraction for Terpane/Sterane Distributions (quantitative)
- GC/MS of Aromatic Hydrocarbon Fraction (quantitative)

Figure 4 is a plot of Doig-sourced oil samples, also reservoired in the Doig, overlaid on the Doig present-day HI map. Integrated data sets of source rock quantity and quality, rock and oil thermal maturity and detailed hydrocarbon parameters allow robust interpretations of potential productivity across the WCSB.

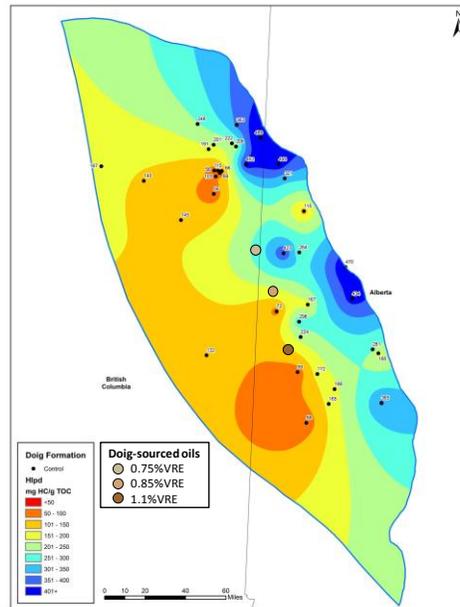


Figure 4. Doig-sourced oil samples overlaying the Doig present-day HI map.

A standardized gas analysis program has been performed on all the GeoMark gas samples in the database and will be completed for new samples. This program consists of gas chromatographic measurement of nitrogen, carbon dioxide, hydrogen sulfide, methane, ethane, propane, iso- and normal butane, iso- and normal pentane, and hexane plus.

Most samples will also be analyzed for stable carbon isotopic composition. An Elementar GC-IRMS is used to measure the $\delta^{13}\text{C}$ composition of methane, ethane, propane, and the butanes, as well as CO_2 .

PVT Analyses

In unconventional and other tight formations where flow issues are critical, PVT analyses have become an important tool in developing successful exploration efforts and follow-on reservoir management. GeoMark has built a very large database of predominantly proprietary PVT reports in the WCSB that will be part of this Project. The objective is to give participating companies a regional understanding of the phase behavior aspects of production, both well-site specific and regionally, and to provide member companies with the tools needed to accurately predict the character (GOR, viscosity, etc.) of production from future wells/regions.

TERMS AND CONDITIONS

The cost of the Project is CAD \$95,000 (Canadian Dollars) per year for a minimum of three (3) years.

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Appendix

GeoMark's WCSB Database

The Internet-accessible database used in design and construction of the GeoMark WCSB Resource Play Atlas facilitates the review, interpretation, and secure storage of geochemical data, plots and other graphics from multiple productive and potentially productive intervals in the WCSB stratigraphic record (Figure 2). The database consists of a series of application-based modules designed for specific analysis, exploration and exploitation functions. All modules within the database structure are exportable to databases holding other types of data (e.g., rock properties, wireline measurements, and seismic attributes).

This new WCSB database is resident within the GeoMark RFDbase (Rock and Fluids Database). The various rock and fluid analytical modules of the database can be viewed at <https://rfdbase.geomarkresearch.com>. The website contains a demonstration routine allowing visitors access to all search and display functions on a limited set of selected samples. Please contact GeoMark for a full demonstration of the RFDbase program.

Database Design

RFDbase has been developed as an interactive web interface overlaying a Microsoft SQL Server database populated with petroleum rock and fluid data. The database applications are hosted off-site offering electronic and physical security, as well as broadband access for member companies.

It is important to note that GeoMark has previously constructed geochemical database modules; much of the data were generated using consistent methods in our laboratories. However, portions of the remaining modules are populated with data from other laboratories where inconsistencies may exist between experimental methods and processing techniques. Where possible, these variations are recorded and quantified in the database.

Data Search & Mapping Functions

All types of data can be identified by multiple search functions. A "Quick Search" function allows a user to search on a series of common sample identifiers such as Country, Basin, or Well Name. A more comprehensive "Detailed Search" can be accomplished applying a user-defined attributes search within a single module (e.g., oils only), or within multiple modules (e.g., oils plus gases). Since all samples in RFDbase are coded with latitude and longitude values for placement on the internet-enabled map, a Geographical Information System (GIS) mapping application provides for a "Map Search" function identifying samples in a more visual environment.

Data Integration

All types of reservoir fluid data are stored in RFDbase. The Database currently holds modules for oil, oil seep, gas, gas seep, mud gas, PVT, flow assurance (wax and asphaltene), water analyses, source rock and source-rock extract analyses.

Downloading Data

Users have a number of options for printing and/or downloading data. GeoMark's standard Geochemical Summary sheet can be viewed on screen or printed. Data tables can be downloaded in several format types, including Microsoft Excel or Microsoft Access. Graphical data can be viewed on screen, or downloaded in report format. Raw GC and GC/MS data, as well as original PVT documentation, are also downloadable from the website.

Database Security

All data/reports are protected with cascading levels of user access based upon established permissions. Levels include Open access, Corporate access, and Proprietary access for tight-hole wells.