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Geoscience BC

Targeted Energy Resource Studies in the Bowser and Sustut Interior Basins of British Columbia
Études des mesures d'économie d'énergie dans les bassins intérieurs de Bowser et de Sustut de C.-B.

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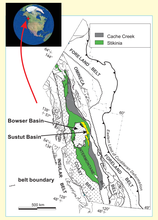
INTRODUCTION



The Bowser and Sustut basins are located in the Intermontane Belt of the Canadian Cordillera, a region of low metamorphic grade (mainly greenschist facies and lower) relative to the bounding metamorphic and plutonic Omineca and Coast belts.

The Bowser and Sustut basins are large (>62,000 sq, km combined) Interior Basins of Jurassic and Cretaceous age in north-central British Columbia. They have been under-explored in terms of hydrocarbon resources because of widespread misperceptions of their prospectivity, largely due to the reconnaissance nature of all geoscience work there until recently. This 2 year project focuses on specific, *detailed*, energy resource studies complementary to an ongoing *regional* project that has been a collaboration between the Geological Survey of Canada (GSC) and the British Columbia Ministry of Energy and Mines (BCMEM) (Evenchick et al., 2005). The project includes three elements of research and compilation: apatite fission track thermochronology (AFTT) of the southern basins; detailed study of the early Bowser Basin history and structural development; data management, integration, and digital publication. The sample analysis and interpretation of AFTT data are critical to understanding petroleum systems in sedimentary basins, which is an essential element of a geoscience/resource framework on which to base sound exploration decisions. Mapping in targeted areas will provide detailed field data on the important early history and geometry of the basin. Data management, integration, and publication are critical because *communication* of data and interpretations are essential to attracting investment to the region.

This poster outlines the three elements of this project, describing the nature of work and their relationship to the broader GSC project. It also presents the status of the project. Details of work on the early Bowser Basin history are presented in a separate poster by J. Waldron and others.

GEOLOGICAL AND HYDROCARBON RESOURCE OVERVIEW OF THE BOWSER AND SUSTUT BASINS

REGIONAL STRATIGRAPHIC FRAMEWORK

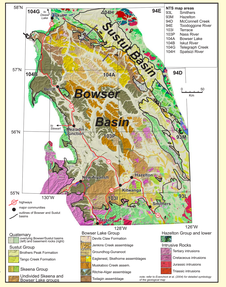
The region is underlain by three stratigraphic successions, in part overlapping in age.

The **Bowser Lake Group** ranges in age from late Middle Jurassic to mid-Cretaceous. Strata were deposited in distal submarine fan, slope, shallow marine shelf, deltaic, fluvial, and lacustrine environments.

The **Skeena Group** is Early Cretaceous to mid- Cretaceous age. Sediments were deposited in primarily nonmarine environments, with local volcanic influences in the southern Bowser Basin.

The **Sustut Group** is mid- to latest Cretaceous age and occurs along the northeast side of the Bowser Basin. Sediments were deposited primarily in fluvial and lacustrine environments. Strata unconformably overlie deformed Bowser Lake Group and Stikinia strata. The basin had eastern (Omineca Belt) and western (cannibalized Bowser Lake Group) sources, a result of formation of the Skeena Fold Belt.

"Basement" The basin successions overlie Stikinia, a terrane accreted to the western margin of North America in the Early to early Middle Jurassic. Units include Devonian to Early Jurassic volcanic arc successions. New data indicate that although these rocks are stratigraphic basement to the Bowser and Sustut basins, not all are economic basement.



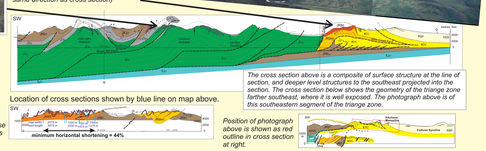
Regional geologic map of the Bowser/Sustut basins area and lithofacies assemblage map of the Bowser Basin, from Evenchick et al., 2005.

REGIONAL STRUCTURAL FRAMEWORK

Skeena Fold Belt
Resolution of Skeena Fold Belt geometry is a fundamental advance in the understanding of Bowser and Sustut basins evolution and resource potential. First order characteristics of the fold belt are: 1) folds in most of the belt trend northwest, are close to tight, and upright to inclined to the northeast; 2) thrust faults are present, but difficult to recognize because Bowser Lake Group lacks distinctive regional stratigraphic markers; 3) contractional structures affect underlying volcanic, clastic, and carbonate successions of Stikinia; 4) the fold belt accommodated a minimum of 44% horizontal shortening; 5) it terminates to the northeast in a triangle zone within Sustut Group; and 6) it is rooted in the Coast Belt to the west. Orogenic shortening began prior to Albian (mid-Cretaceous) time, and continued at least into the Maastrichtian (latest Cretaceous). The Sustut Group and Devils Claw Formation are both synorogenic clastic basin fill associated with formation of the fold belt. Primary orogenic structures, including a triangle zone, are important structural elements that must be considered in a revised petroleum assessment.

Folded Hazelton Gp volcanics in hanging wall and footwall of thrust fault.

Folds and northeast dipping contractional fault in Tango Ck Fm (KTC) in triangle zone at the northeast front of the Skeena Fold Belt. Monocline forming northeast roof of triangle zone is at far right. (photo reversed to view in same direction as cross section)



The cross section above is a composite of surface structure at the line of section, and deeper level structures to the southeast projected into the section. The cross section below shows the geometry of the triange zone farther southeast, where it is well exposed. The photograph above is of this southeastern segment of the triange zone.

Cross section at right illustrates the difference in scale of folds between those in Bowser Lake Gp distant to competent units of volcanics and those in Bowser Lake Gp near the volcanics (upper right cross section).

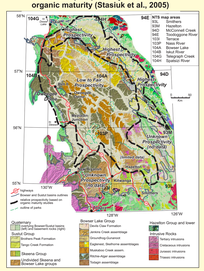
Position of photograph above is shown as red outline in cross section at right.

HYDROCARBONS

The Bowser and Sustut basins are considered to be frontier hydrocarbon basins. They are large Mesozoic clastic basins in which the style of deformation, which includes a classic triangle zone locally in the northeast, provides ample opportunities for structural traps of hydrocarbons. Stikinia includes minor carbonates that could potentially be source rocks, and the Bowser Basin includes a huge volume of dark grey siltstone and mudstone which are potential source rocks.

The regional Bowser/Sustut project aims to provide basic regional geological and resource framework data and interpretations upon which to base more informed exploration decisions. Fieldwork over the past 3 field seasons has contributed to significant refinements of the distribution of map units. Early results of regional energy resource studies showed that the basin is not entirely overmature (Evenchick et al., 2002), and that there are at least 3 effective petroleum systems that at some point have generated, expelled, and accumulated crude oil (Osadetz et al., 2004). Hydrocarbon source rocks identified are a sub-Hazelton carbonate, upper Hazelton or lower Bowser marine strata, and Mesozoic lacustrine strata. Recent results (Stasiuk et al., 2005) indicate that the most prospective parts of the basins (in the early oil to condensate-dry gas generation stage of thermal maturation) are in the northeast Bowser Basin and an elongate belt in the east, overlapping the Sustut Basin and eastern Bowser Basin (see diagram below).

Energy resource studies now need to focus on specifics of timing of petroleum generation and migration, and peak temperatures. The analytical parts of the current (Geoscience BC) project will address these through apatite fission track thermochronology. Following up on the 2004 regional mapping, one element of this work is a detailed field examination of the early history of the Bowser Basin, which includes an interval known locally to include organic-rich shale (Thomson et al., 1986).



TARGETED ENERGY RESOURCE STUDIES COMPLEMENTARY TO THE REGIONAL BOWSER/SUSTUT PROJECT

1 APATITE FISSION TRACK THERMOCHRONOLOGY

The timing of hydrocarbon generation relative to the formation of structures affects petroleum play and prospect level risks. Organic maturity provides a maximum recording geothermometer which indicates regions of probable petroleum generation, whereas apatite fission-track thermochronology (AFTT) provides an integrated thermal history for the period when samples last cooled from ~>110°C to ~<60°C. Therefore AFTT provides potential constraints on the age of structures, at various scales, which can be combined with petroleum system models to constrain play and prospect risks for petroleum accumulation. Preliminary results of samples from parts of the northern Bowser and Sustut basins (O'Sullivan et al., 2005) record 3 periods of rapid cooling (from temperatures > 100-110°C) with differences between different parts of the basins. Rocks presently at the surface were within the zone of thermogenic petroleum generation until either latest Cretaceous (in the northwest and locally northeast) or at least Middle Eocene (the remainder of the region sampled). Therefore, most of the samples appear to record rapid, regional events that post-date Skeena Fold Belt structures, highlighting the potential for structural traps in those areas. All AFTT samples analysed to date are from the northern 2/3 of the Bowser and Sustut basins (see figure at right). These samples were collected in 2002 (by K. Osadetz, C. Evenchick, F. Ferri, and N. Wilson) and analysed (by P. O'Sullivan, Apatite to Zircon Inc.) under a research agreement between the Geological Survey of Canada and the BC Ministry of Energy and Mines. New sampling in the southern basin, undertaken during the current project, was conducted in concert with mapping by the broader Bowser/Sustut project and addresses the following issues:

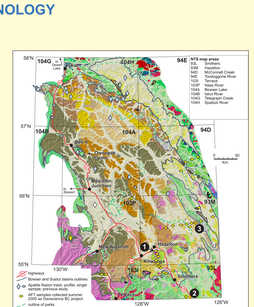
- a vertical profile in a high-relief Cretaceous intrusion will establish a well constrained geothermal gradient for the southern basin region, which will enhance thermal history modelling of other samples.
- current geological maps of the southeast Bowser Basin (e.g. Richards, 1990) display a rectilinear pattern of normal faults. This interpretation is based on the presence of young rocks in valleys and a model of Tertiary extension. However, the faults are poorly exposed and alternatives exist to explain the map pattern. AFTT results, when combined with mapping can elucidate the nature and significance of the faults by placing constraints on their timing and magnitude of displacement. This is important for petroleum exploration because the map pattern could be interpreted as resulting from fold and thrust belt structures similar to those farther north. The geometric difference between the two interpretations is fundamental to any attempt to extrapolate structures and units to depth. Therefore the resolution of the dominant structural style is an issue critical for petroleum assessment and planning geophysical surveys or drill programs. Mapping in 2004 in west 93M (Ferri et al., 2005) suggests that several faults shown on the previous map are not required by the distribution of map units.
- AFTT results from Tertiary units will provide a thermal history for a younger period than existing samples, extending into the period of inferred rapid cooling for farther north.
- AFTT results from samples collected from the southern Sustut Basin will be used to compare and contrast with those previously collected from the northern basin, and to determine when rocks in the southern Sustut Basin were within the temperature range for generating petroleum.

Initial data will be released as available; a final report will integrate these new data with other pertinent datasets.

Status of research
In 2005 29 samples were collected to cover the issues listed above. Two transects cross several of the inferred faults. The location of new samples is shown in the map to the right.

All samples have been sent to Apatite to Zircon, Inc., where they have been crushed, and all mineral separations have been completed. All samples yielded enough apatite for eventual analysis, with the majority of the samples yielding 100's to 1000's of grains. As of mid January '06, grain mounts for AFT analysis, including confined track length measurements, have been prepared, and spontaneous track counts have been completed. Analyses are expected to be completed by mid February. Initial data release will be in spring 2006.

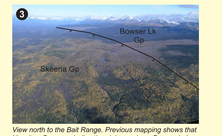
Field observations indicate that fold and thrust belt structures in the southern Bowser Basin are widespread. They affect sub-Bowser strata, all units of the Bowser Lake Group, and the Skeena Group. The degree to which the present structural relief is a result of normal faults rather than contractional structures will be addressed with further analysis of the field data, and its integration with apatite fission track thermochronology.



Geological compilation of the Bowser and Sustut basins on shaded relief map (modified after Evenchick et al., 2004), showing locations of detrital zircon samples collected in previous work and this work, and showing study areas for early Bowser Basin history field studies.

Gareth collecting AFT sample from Cretaceous granite at the top of Hagwilget Peak (Rocher Deboule Range).

Tertiary volcanic/clastic unit sampled for AFT southeast of Smithers



View north to the Bait Range. Previous mapping shows that Hazelton Group underlies the alpine regions, Bowser Lake Group underlies the treed slopes on the southwest flank of the Bait Range, and Skeena Group underlies much of the valley. Range. The inferred major normal fault is shown in approx. position, separating Skeena from Bowser Lake Group.

2 EARLY BOWSER BASIN HISTORY AND STRUCTURAL ANALYSIS

This study led by Dr. John Waldron (University of Alberta) focuses on potential source rocks and structures in the transition from a volcanic-dominated, rifted arc environment (Hazelton Group) to a sedimentary basin (Bowser Lake Group). Previous work identified major lateral facies changes in this transition, in the northwest part of the Bowser Basin (Oweegee dome area). In this area volcanics and coarse volcaniclastic rocks of the lower Hazelton Group are separated by a conspicuous unconformity from laminated, thinly bedded siltstones of the upper Hazelton Group. The latter contain tuffaceous bands, occasional intercalations of bioclastic limestone, and localized spectacular mound-facies limestones; it is unknown whether the mound-facies limestones represent in-situ reefs or olistoliths that slid in from basin margins. The upper Hazelton rocks, including the limestones, are organic-rich, and may have acted as source rocks for petroleum during burial and deformation of the basin. The lower Bowser Lake Group on the east side of Oweegee dome illustrates a shallowing of facies, with the deposition of bioturbated shelf clastics. In contrast, elsewhere the dome appear to have been submerged in thick turbidite successions (Evenchick et al., 2005). These observations indicate that Oweegee dome may be founded on a primary feature of the basin floor, modified by later deformation. Bowser strata around Oweegee dome display a pattern of folding, locally with weak cleavage development, involving intersecting NW-trending and NE-trending folds, producing structural domes and basins. Evenchick (2001) suggested that the transverse folds were related to strike-slip motion. Evidence for the relative timing of the two sets of folds is contradictory.

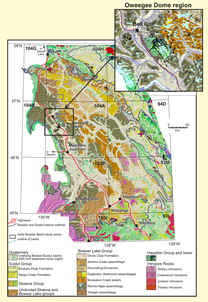
The objectives of the work are:

- to determine stratigraphic relationships in the Hazelton-Bowser transition, in order to understand the tectonic processes involved in initiation of the basin and the role of the Upper Hazelton as a potential source rock; and
- to determine the origin and relative timing of transverse structures responsible for domes and basins within the basin, aimed at understanding their relationship to potential petroleum traps.

As an additional benefit the work will provide an improved regional understanding of the stratigraphic interval which farther west is extensively mineralized, and contains the Eskay Creek gold mine.

The work is undertaken by two graduate students (W. Loogman and J.-F. Gagnon) under the supervision of Dr. J. Waldron. Gagnon works on relationships in the Hazelton-Bowser transition, to define the lithologies, lateral relationships, and tectonic setting of the sedimentary rocks. Loogman focuses on transverse structures and folds in the Bowser Lake Group. Fieldwork focussed on the Oweegee dome area in 2005.

Status of research
Field work was completed successfully, and is reported on in a separate poster by Waldron and others.



Jamel downloading data from handheld computers after a day of road traverses.

3 DIGITAL ASPECTS OF THE FIELD-TO-PUBLICATION PROCESS

Critical links in the path from field observation to communication and publication include a wide range of digital and organizational work in parallel with the scientific work. This includes: maintaining/upgrading an application for digital capture of field data (using handheld computers); managing data in the field; follow-up checking and cleaning of databases; rectification of aerial photographs used in the cartographic process; extracting data subsets for analysis and distribution; compiling archival data from previous field work in the region with current work; maintenance of the project website; creation of CD's of recent project presentations and results for distribution at major meetings; customization of specialized tools for integration, display, and communication of themed datasets for final compilation release; sample curation and distribution of the various sample suites to labs; digital graphics for publications; analysis of datasets. For example, the time involved in the publication process alone for the deliverables of the other elements of this targeted project for 05/06 will require 6 weeks. This work is fundamental to communicating results and putting new data and interpretations into the hands of explorationists for decision making.

Status of work
The primary deliverable for this work is an Open File release of digital field data on CD from all mapping seasons, to be completed in 2007. Work is progressing this year on data verification, capture of past field data, and design of the final synthesis format.

Example of database currently used by project participants to check data collected in the summer, and to access data of all mappers for analysis and compilation.

RELATIONSHIP TO BROADER BOWSER/SUSTUT PROJECT

The regional Bowser/Sustut project provides regional context for the complementary targeted energy resource studies presented in this poster. The project "Integrated Petroleum Resource Potential and Geoscience Studies of the Bowser and Sustut Basins" (referred to hereafter as the Bowser/Sustut project) is a project of the GSC's Northern Resources Development program. It started in 2003 as a collaboration between the GSC and BCMEM Oil and Gas division. The primary goal is to provide improved geoscience data and knowledge regarding energy resources of the Bowser and Sustut basins, in order to spark new private sector investment. It is regional in scope, covering the breadth of the Bowser and Sustut basins. The final of many project deliverables will be a digital basin atlas, including resource assessment. The project has involved 22 GSC scientists and technicians; 1 BCMEM scientist (F. Ferri) and 1 faculty member (Dr. P. Mustard) and 1 graduate student (G. Smith) from Simon Fraser University. With this new targeted project we include one outside consultant (Dr. Paul O'Sullivan), and one faculty member (Dr. J. Waldron) and 2 graduate students from the University of Alberta. GSC scientists involved in the project include specialists in a wide suite of geoscience and energy resource studies all aimed at an integrated understanding of energy resources of the basins (e.g. biostratigraphy, paleomagnetism, geophysics, geochronology, structural geology, basin stratigraphy, organic petrology, thermal maturity, petroleum systems, resource assessment). These are complemented by a small team dedicated to cartography, graphics, database management, information management, website creation and maintenance, development of tools for capturing field data digitally and integrating digital data for publication, and outreach. This group is critical to rapid and broad communication of results.

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