NEW DATA ON COOLING HISTORY OF THE SOUTHERN BOWSER BASIN, DEFORMATION AND EARLY BASIN SEDIMENTATION IN THE NORTHERN BOWSER BASIN, AND PROGRESS ON DIGITAL FIELD DATA COMPILATION

C.A. Evenchick[1], P.B. O'Sullivan[2], J. Joseph[1], D. Ritcey[1], J.W.F. Waldron[3], J.F. Gagnon[3], and W. Loogman[3]

[1]Geological Survey of Canada, 625 Robson St., Vancouver B.C.; [2]Apatite to Zircon Inc., Viola, ID, USA; [3]Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton AB

Geological Survey of Canada
Commission géologique du Canada

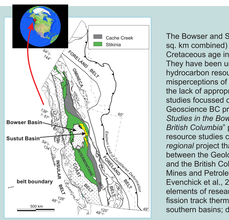
Geoscience BC

Northern Resources Development
La mise en valeur des ressources du Nord

Secure Canadian Energy Supply
Sécurité de l'approvisionnement énergétique du Canada

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 lack of appropriate mix of regional and detailed studies focussed on energy resources. The 2 year Geoscience BC project "*Targeted Energy Resource Studies in the Bowser and Sustut Interior Basins of British Columbia*" provides 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 and Petroleum Resources (BCMEMPR; 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 and their status. Research on the early Bowser Basin history and structural relationships are conducted by University of Alberta graduate students J.F. Gagnon and W. Loogman, under the supervision of J. Waldron; further details of their work are presented in separate posters.

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, modified from Evenchick et al., 2006.

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 northwest 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).

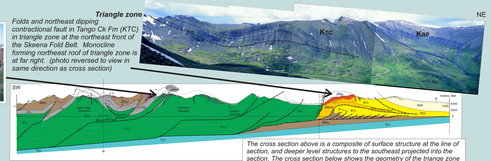
REGIONAL STRUCTURAL FRAMEWORK

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.

Involvement of Stikinia

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

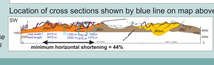
Triangle zone



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)

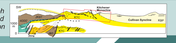
The cross section above is a composite of surface structure at the line of section, and deeper level structures to the southeast projected into the section. The cross section below shows the geometry of the triange zone farther southeast, where it is well exposed. The photograph above is of this southeastern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

Location of cross sections shown by blue line on map above.



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



1 EARLY BOWSER BASIN HISTORY AND STRUCTURAL ANALYSIS

Stratigraphic Record of Initiation of Sedimentation in the Bowser Basin

J.-F. Gagnon, W. Loogman, J.W.F. Waldron, F. Cordey and C.A. Evenchick

Systematic measurements of detailed stratigraphic sections were conducted in order to document the onset of sedimentation in the Bowser Basin. This work has important applications to petroleum systems within the Bowser Basin because potential source rocks have been previously identified at this specific stratigraphic level without a clear understanding on how they relate to reservoir rocks in adjacent units. Based on the observations made in measured sections, it appears that continuous sedimentation took place over a regional unconformity in a tectonically active, shallow marine basin on Stikinia from the early Pliensbachian to early Bajocian. Depending on the distance from volcanic centres, the deposition style of the Spatsizi Formation and equivalents is quite variable on the basin scale. For instance, the Pliensbachian to Bajocian fine-grained sedimentary rocks at Todagin Mountain are interbedded with thick intervals of marine pillow basalt and hyaloclastite (Figure 1), whereas calcareous fossiliferous sandstone and siltstone of the same age in the Mount Will district show only minor volcanic input. Rapid lateral facies change and the variability of sediment thickness in the upper Hazelton Group, documented by Thomson et al. (1986) and others, are attributed to active normal faulting during an extensional back-arc stage that isolated multiple sub-basins. Following the end of magmatism, thermal relaxation of the crust combined with eustatic sea-level rise generated new accomodation space in the basin where condensed, organic-rich deepwater sediments accumulated. Ricketts et al. (1992) suggested that crustal loading during accretion of Stikinia to North America contributed a component of lithospheric flexure to subsidence. In all the sections investigated during this study, the transition from the upper Hazelton Group into the Bowser Lake Group appeared concordant and gradational, in contrast to conclusions of Thomson et al (1986), but consistent with Evenchick and Thorkelson, 2005. Ongoing work for this project includes finalizing geological maps of the study areas, petrographic analysis of volcanic and sedimentary rocks, and defining constraints on the subsidence history of the Bowser Basin using geochronology, paleontology and sedimentology.

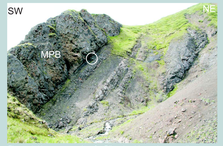
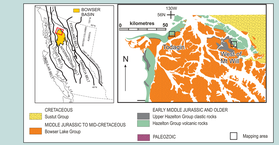


Figure 1. Uppermost units of a Pliensbachian volcano-sedimentary succession showing thinly laminated fossiliferous siltstone and shale overlain by a thick unit of marine pillow basalt (MPB), west of Todagin Mountain. See person in the circle for scale.



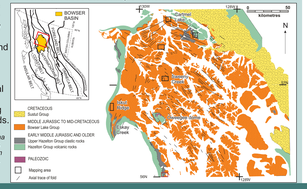
Simplified regional geologic map of the northwest Bowser Basin showing 2006 study areas. Inset: Location of map within the Canadian Cordillera.

Structural Overprinting in the northwest Skeena Fold Belt

W. Loogman, J.-F. Gagnon, J.W.F. Waldron, and C.A. Evenchick

Six areas were mapped at 1:25,000 scale in the 2006 field season, complementing seven areas mapped in 2005. Detailed structural mapping was completed with the intention of defining the degree to which multiple phases of deformation had occurred in selected areas, or whether they represented domains of a single deformation. The interpretation of timing of deformation and subsequent application to timing of regional fold sets is a major component of research being carried out. This work has important applications to petroleum systems analysis within the Bowser Basin with relation to trap development and timing of structures relative to petroleum migration.
Within the areas mapped variations in structural style are evident. All areas were structurally dominated by folds, but fold wavelength and orientation vary greatly from one area to another. Areas with the clearest timing relationships are Iskut ridge, Sweeny Creek, and Cartmel Lake (see map below). The Iskut ridge area revealed north-northeast trending folds that were clearly overprinted by outcrop-scale folds trending southeast, resulting in mapped deflections in fold axial traces. The Sweeny Creek area shows north-northeast-trending folds with down-plunge steepening inferred to result from regional northwest-trending folds.

The Cartmel Lake area has major northwest-trending folds that are not offset by a fault associated with a northeast trending fold, implying the fault pre-dates later folding.
In summary, all areas mapped in 2006 exhibit evidence of structural overprinting, though not always in the form of intersecting folds. In areas where timing relationships of structures are evident there is a consistent relationship of northwest-southwest shortening, followed by northeast-southwest shortening. Ongoing work includes finalizing maps and interpretations for publication in all areas, petrographic analysis of sampled cleavage, strain analysis, and geochronological dating of local intrusions and cleavage to constrain absolute timing of deformation in various areas.



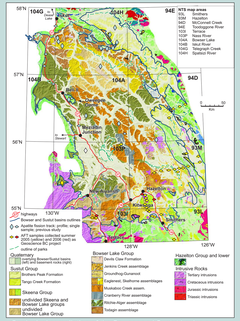
Simplified regional geologic map of the northwest Skeena Fold Belt showing fold axial traces and areas mapped in 2006. Regional structures and basin map compiled from Evenchick (1991), Bone (2002) Evenchick et al., (2004). Inset: Location of map within the Canadian Cordillera.

2 APATITE FISSION TRACK THERMOCHRONOLOGY

P.B. O'Sullivan, C.A. Evenchick, K.G. Osadetz

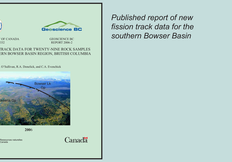
Project Rationale
The timing of hydrocarbon generation relative to the formation of structures affects petroleum play and prospect level risks. The study of organic maturity provides a maximum recording geothermometer which indicates regions of probable petroleum generation, whereas apatite fission-track 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 the northern Bowser and Sustut basins (O'Sullivan et al., 2005) record 3 periods of rapid cooling. 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 regional events post-dating Skeena Fold Belt structures, highlighting the potential for structural traps in those areas, but the risk of associated fractures ruining trap integrity.
Prior to this study all AFTT samples analysed were from the northern 2/3 of the Bowser and Sustut basins (see figure at right). 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. However, the faults are poorly exposed and the map distribution may be explained in many places without faults. 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 extrapolation of structures and units to depth and is critical for petroleum assessment, and planning geophysical surveys or drill programs.
- AFTT results from Tertiary units will provide a thermal history for a younger period than existing samples.



Geological compilation of the Bowser and Sustut basins on shaded relief map (modified after Evenchick et al., 2006), showing locations of detrital zircon samples collected in previous work and this work.

Status of research
29 samples were collected in 2005 to address the issues listed above. Two transects cross several of the inferred faults. Poor weather in 2005 prevented collection of all desired samples; the remaining 3 samples were collected during a short field visit in 2006. The locations of samples in the southern basin region are shown in the map to the upper right.
The 29 samples collected in 2005 were processed and analysed by staff of Apatite to Zircon, Inc., and have been published in O'Sullivan et al., Geoscience Report 2006-2, GSC Open File 5332. Data for the final 3 samples will be published by April 30, 2007.
Preliminary interpretation of the results suggest that most, but not all, of the sedimentary rocks were heated to temperatures great enough to fully reset the previous AFTT ages, and now record rapid cooling in the Cenozoic through temperatures ranging from ~>110˚C to ~<60˚C .
Full interpretation to resolve the question of the degree to which the present structural relief is a result of normal faults rather than contractional structures will be addressed by integrating the detailed interpretation of AFTT data with field and geophysical data. Field observations indicate that fold and thrust belt structures are widespread in the southern Bowser Basin, affecting sub-Bowser strata, all units of the Bowser Lake Group, and the Skeena Group.



Published report of new fission track data for the southern Bowser Basin

Jamel Joseph sampling Eocene-Oligocene strata in 2006 to constrain the Cenozoic cooling history.

3 DIGITAL ASPECTS OF THE FIELD-TO-PUBLICATION PROCESS

J. Joseph, M. Quat, D. Ritcey

In 2003, the Bowser Basin project began using digital data collection devices to store field data. Palm® handheld devices, along with the Pendragon Forms software, replaced the standard field note book as the primary data storage tool in the field. These new tools allowed the scientists to collect field data in a standardized format that was readily available to view on computers at field camp. There are many advantages to having the data in a digital format while in the field, such as giving the geologists a visual look of the overall geology of the area that they traversed that day, as well as looking at data collected by other members of the field party throughout all field seasons. These new tools aided in the decision making for the project leaders when determining future traverses. Follow-up checking and cleaning of these databases have yielded data sets that have been used in many publications and maps, and are stored in a format (Microsoft Access©) that allows many professionals to use these data in a multitude of ways to obtain their desired products.
Data collected between 1985 and 2003 were stored in field note books initially and point data were entered digitally in various formats. The notebooks and point data have been converted into the same digital format as the current project, using forms created in Microsoft Access® and are now available for use in publications and maps.
The project website (www.bowserbasin.com) contains background information about the Bowser Basin as well as specific data collected by the project geologists using these new digital data collection tools. The website is updated frequently and contains news, links, and photos that are beneficial to those interested in working in the Bowser Basin.
Bowser Basin Geosamplers (Project information CD's), contain basic data, as well as posters, presentations, and other useful data files from past conferences and workshops for those interested in learning more about the Bowser Basin. They are distributed at conferences, workshops, and other meetings free of charge and can be obtained by asking any of the project participants.

Data Collection 2003 to 2006

1) The forms were created by J. Joseph using Pendragon Forms

2) The forms were loaded on the Palms to be used by geologists for recording all their field data.

3) The geologists would enter their observations into the forms while on traverse.

4) At the end of the day, the data was downloaded from the handheld into a Microsoft Access database.

5) The geologists can view the data spatially or tabularly once downloaded and can query the data to gain a quicker and more thorough understanding of the areas they were in, leading to a better overall knowledge of the area and helping determine where / what should be done in the future.

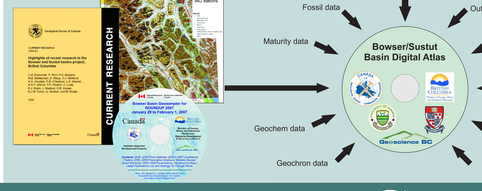
Data Collection Pre-2003

1) Legacy data was recorded in field note books; point data were in dbf and excel files.

2) Basic station data, but little descriptive information, was entered into the database using custom forms. Previous point data files were incorporated into the new database, as were fieldtag files for 1995 and 1996.

Final Geoscience BC Product:
The primary deliverable for Geoscience BC is a release of all the digital field data and files on DVD(s). Work is progressing well; most of the data have been checked and verified, most of the archived data collected in note books have been converted into a digital format, and the final design and functionality of the DVD(s) is in progress. This DVD will contain all the field data collected from 1985 to 2006, a photo gallery, as well as GIS datasets and many other files relating to the Bowser and Sustut basins. All will be integrated with maps and publications to produce the Bowser/Sustut Digital Basin Atlas, the final product of the broader Bowser/Sustut project. The scheduled release date for the Geoscience BC report is summer 2007.

The field data has been used for research as well as in many products, such as maps, publications, CD's, and will be included in the final compilation DVD.



Natural Resources Canada
Ressources naturelles Canada

Canada