ES09: In honour of John Clague, one of Canada's foremost Earth Scientists

Conveners: Brent Ward[1], and Brian Menounos[2]

Co-chairs: Brent Ward[1], and Brian Menounos[2]

[1] Earth Sciences Dept., Simon Fraser University, Burnaby, BC, V5A 1S6
Phone: 778-782-4229 Fax: 778-782-2456, E-mail: bcward@sfu.ca
[2] Geography Program and Natural Resources and Environmental Studies Institute, University of Northern British Columbia, Prince George, BC, V2N 4Z9 Phone: 250-960-6266 Fax: 50-960-6533, E-mail: menounos@unbc.ca

Session Description
Over the last 40 years John Clague substantially advanced Earth sciences both in Canada and within many mountainous countries. John's major contributions lie within the sub-disciplines of Quaternary Geoscience, Geomorphology and Environmental Change. To celebrate John's recent retirement we invite scientists to contribute either review or original papers that focus on aspects of Quaternary research (geomorphology, geochronology, landslides and seismicity). We especially encourage scientist who worked closely with John or were his former students.

Primary Affiliation: Biogeosciences / Earth Surface Processes / Hydrology

---

NOTE: THIS DOCUMENT CONTAINS INFORMATION FOR ALL SESSION SUB-SECTIONS. PRESENTER ABSTRACTS ARE FOUND AT THE END OF THE DOCUMENT.

SCHEDULE MAY BE SUBJECT TO CHANGE.

ORAL SESSION ES09a

Chairs: B. Ward and B. Menounos **Room: GEOG 229**

Wednesday, May 31st

TIME	AUTHORS	TITLE
9:00	N.W. Rutter	John Clague: Friend and Colleague
9:30	Gerald Osborn, Kaylee Norsworthy, and Chuck Blay	Development and maintenance of the fluted cliffs of the Na Pali coast, Kauai, Hawaiian Islands
9:45	Douglas H. Clark	Showdown at the border: revisiting the long-standing Sumas controversy across the 49th Parallel
10:00	Marten Geertsema, John Clague, Brian Menounos and Timothy Jull	Radiocarbon constraints on ice sheet cover in northeastern British Columbia
10:15	Olav B. Lian	The Timing and Character of Postglacial Fluvial Incision, Fraser River Valley, South-central British Columbia

ORAL SESSION ES09b

Chairs: B. Ward and B. Menounos **Room: GEOG 229**

Wednesday, May 31st

TIME	AUTHORS	TITLE
14:00	Pierre Friele, James Wetherill, Tom Millard, Ryan McQueen and John Clague	Temporal and spatial patterns of debris flow activity, Hatzic Valley, Lower Mainland BC: implications for geomorphic risk assessment
14:15	Giacomo Falorni, Leila Ertolahti, Gioachino Roberti, Brent Ward, Jean Pascal Iannacone, Geidy Baldeon and John Clague	Applications of InSAR ground deformation measurements in southern British Columbia
14:30	Marco Giardino, Luigi Perotti, John Clague, Brent Ward	The "geoNatHaz" experience and the enhancement of international Earth science competence in natural hazards and risks
14:45	Carie-Ann Lau , Caterina Zei, John Clague, …	Effects of landslide and flood-induced sediment pulses on the geomorphology of the Upper Lillooet River Valley
15:00	Lambertus C. Struik and Laurie D. Pearce	A research – policy connection to reduce urban disaster losses: Risk-based land use
15:15	Nicholas J. Roberts, René W. Barendregt, John J. Clague	Late Pliocene and Early Pleistocene glaciation of the tropical Andes

ORAL SESSION ES09c

Chairs: B. Ward and B. Menounos **Room: GEOG 229**

Wednesday, May 31st

TIME	AUTHORS	TITLE
16:00	Duane Froese	The end of the Pleistocene in the northern Cordillera and the importance of Allerod warming on rapid ecosystem changes
16:30	Britta J.L. Jensen, Alwynne B. Beaudoin	Revising the Tephrostratigraphy of Alberta
16:45	Alberto V. Reyes	Glacier fluctuations, ice-dammed lakes, and regional hydrology: John Clague's geological crystal ball in the St. Elias Mountains
17:00	Daniel H. Shugar, John J. Clague, James L. Best, Christian Schoof, Michael J. Willis, Luke Copland, Gerard H. Roe	Inspector Kaskawulsh and the Case of the Disappearing River
17:15	Jon L. Riedel	From the Halls of Simon Fraser to the Shores of Lake Concrete: Applying the Clague Method to Skagit Valley, Washington and British Columbia
17:30	Brian Menounos , Jeremy Venditti, Eva Kwoll, John J. Clague, Michael Church, Brent Goehring	Evolution of Fraser Canyon, British Columbia, Canada

POSTER SESSION ES09

Chairs: B. Ward and B. Menounos **Room: ESB Atrium**

Wednesday, May 31st

Poster No.	AUTHORS	TITLE
P01-ES09	Marta Chiarle, Giovanni Mortara, Luigi Perotti, Marco Giardino	Glacier-related hazards in a changing mountain environment: an Italian-Canadian perspective
P02-ES09	Janice Brahney1 , Brian Menounos2, Thomas W.D. Edwards3, and John Clague4	Cause and Consequence of Lake Level Change in Kluane Lake, Yukon Territory

P03-ES09	Andrée Blais-Stevens , John J. Clague, Menounos, B., and Brahney, J.	Paleoseismic evidence for repeated Holocene displacements along the Denali Fault in southwest Yukon Territory
P04-ES09	Nancy Calhoun, John J. Clague, and Andreas von Poschinger	The catastrophic Flims landslide and associated Bonaduz gravel, Vorderrhein River Valley, Switzerland
P05-ES09	Lionel E. Jackson Jr.[1] and Brent C. Ward[1]	A Late Pleistocene stratigraphic record from geotechnical drilling, Evergreen Line Tunnel, Greater Vancouver, BC

SUBMITTED ABSTRACTS

ES09-01 John Clague: Friend and Colleague

Nat Rutter[1]

[1]Dept. of Earth and Atmospheric Sciences, University of Alberta
Edmonton, AB T6G 2E3 Phone: 780 963 5163 E-mail nat.rutter@ualberta

Abstract
I'm a half-generation ahead of John, so I have been able to follow his career in real time, from his days at the Geological Survey of Canada to his tenure at Simon Fraser University. If you work in the Quaternary, you know his name. In the past thirty years or so, he has been the major voice of the Quaternary of the Cordilleran area, from his early work in the Cranbrook area and later in other parts of B. C. from Haida Gwaii to Kluane. He has been able to tie his studies on glaciation to his undertanding , among other things, of sea level changes, landslides, and Tsunamis. His academic studies have enabled him to help solve practical problems that have a bearing on the life of the West Coast. He has generously given his time to inform the public. He does leave the Cordilleran on occasion; he has had a project in Argentina for about the past ten years. He has also participated in numerous scientific societies varying from the Geological Society of America, International Union for Quaternary Research, to the Association of Professional Engineers and Geoscientists of British Columbia. He can also be a funny guy. One memorable occasion, on a cruise in the Caribbean, he and Peter Bobrowsky, in Jamaican Dreadlocks, sang "Born to be Wild" to a packed audience. So it is an honor to say something about John's outstanding career. Actually a double honor for me as some of my former students on the west coast (Peter, Brent Ward, Vic Levson, Heather Blyth) have had the opportunity to become friends or colleagues with John. I want to mention Lexi, his wife, who has supported him through out his career. However, I suspect his career is far from over; John will be doing geology for years to come.

Presentation type: Oral Presentation

ES09-02 Inspector Kaskawulsh and the Case of the Disappearing River

Daniel H. Shugar[1], John J. Clague[2], James L. Best[3], Christian Schoof[4], Michael J. Willis[5], Luke Copland[6], Gerard H. Roe[7]

[1] Water, Sediment, Hazards and Earth-surface Dynamics (WaterSHED) Lab, School of Interdisciplinary Arts and Sciences, University of Washington Tacoma, Tacoma, WA, 98402, USA
email: dshugar@uw.edu phone: 253-692-4926
[2] Centre for Natural Hazards Research, Department of Earth Sciences, Simon Fraser University, Burnaby, BC, Canada, V5A 1S6
[3] Departments of Geology, Geography and GIS, Mechanical Science and Engineering and Ven Te Chow Hydrosystems Laboratory, University of Illinois, Urbana, IL 61801, USA
[4] Department of Earth, Ocean & Atmospheric Sciences, University of British Columbia, Vancouver, BC, Canada, V6T 1Z4
[5] Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO, 80309
[6] Department of Geography, Environment and Geomatics, University of Ottawa, Ottawa, ON, Canada, K1N 6N5
[7] Department of Earth and Space Sciences, University of Washington, Seattle, WA, 98195

Abstract
Inspector Kaskawulsh (*nee* Glacier) of the Kluane Police Department has been summoned to investigate the disappearance of Slims River, a notoriously cold and swift character last seen in early May, 2016. All evidence soon points to Slims' brother, Kaskawulsh River, as the culprit. In this talk, we will describe the piracy of Slims River by Kaskawulsh River in Kluane National Park. This is the first documentation of river piracy driven by post-industrial climate change. We use a combination of hydrological measurements and novel tools such as drone-generated DEMs to quantify geomorphic changes in this changing landscape. In the case that we document, the most notable short-term impacts will be adjustments to the planforms of Slims and Kaskawulsh rivers in response to altered flows, and extension of the Kaskawulsh watershed into the now-abandoned headwaters of Slims River. [136 words]

Presentation type: Oral Presentation

ES09-03 Glacier-related hazards in a changing mountain environment: an Italian-Canadian perspective

Marta Chiarle[1,3], Giovanni Mortara[1,3], Luigi Perotti[2,3], Marco Giardino[2,3]

[1] IRPI, CNR, Torino, Italy
Phone: +39-11-3977836 Fax: +39-11-3977821, e-mail: marta.chiarle@irpi.cnr.it
[2] Earth Science Department, University of Torino, Italy
[3] Italian Glaciological Committee, Torino, Italy

Abstract
A systematic study of glacier-related hazards in the Western Alps started in Italy only in the early 1990s, and greatly benefited from the pioneering studies of John Clague. He analyzed natural instability processes in the glaciated environment and their relationship with the climatic and environmental changes taking place since the end of the Little Ice Age. From the beginning of the 2000s, it became clear that environmental changes related to global warming were accelerating so quickly in high elevation and glaciated mountains. An international effort to collect and exchange data was thus required, in order to provide scientists and local administrations with the most advanced knowledge and tools to deal with the impacts of climate change. This was the premise behind the start of a fruitful scientific collaboration developed over nearly 10 years between the authors and John Clague and other Canadian scientists, with the aim to compare geomorphic processes occurring in the high mountains of two distant geographic areas, but with similar physiographic characteristics. In this framework, we analyzed and compared instability events occurred in glacial and periglacial areas of the Italian Alps and of Western Canada, such as landslides, debris flows, glacial lake outburst floods, ice avalanches. We identified the types of instability mainly conditioned by climate change and discussed hazard scenarios. Methodological approaches used in Italy and Canada for studying the impacts of degrading permafrost and glacier ice loss on mountain environments were compared, and strategies for communication and dissemination of results were addressed. Studies have shown differences and similarities among the two areas, which highlight the effects of regional/local physiography and climate and, at the same time, confirm the global scale of the changes underway. These fruitful research results fed educational activities and research training within international academic exchange programs such as GeoNatHaz.

Presentation type: Poster

ES09-04 Cause and Consequence of Lake Level Change in Kluane Lake, Yukon Territory

Janice Brahney[1], Brian Menounos[2], Thomas W.D. Edwards[3], and John Clague[4]

[1] Department of Watershed Sciences, Utah State University, Logan, UT, 84341
Phone: 434-797-4479, E-mail: Janice.brahney@usu.edu
[2] Geography Program and Natural Resources and Environmental Studies Institute., University of Northern British Columbia, Prince George, BC, V2N 4Z9
[3] Department of Earth and Environmental Sciences, University of Waterloo, Waterloo, ON, N2L 3G1
[4] Department of Earth Science, Simon Fraser University, Burnaby, BC, V5A 1S6

Abstract
Kluane Lake, YT, underwent dramatic fluctuations in lake level through the late Holocene. Landscape evidence including a raised bench 12m above current level and drowned trees along the shore suggest historically higher and lower lake levels. We used lake sediment cores to reconstruct the cause, consequence, and timing of these lake level changes. Specifically, we used geochemistry to reconstruct water sources into the basin, sedimentology to examine changes in lake depth, and $\delta^{18}O$ isotopes recorded in water and sediment cellulose to reconstruct the basin hydrology. Changes in lake level resulted from geomorphic changes in the watershed caused by fluctuations in climate and glacier extent. Out results indicated that from 5000-1300 Cal Yr. BP the lake was 22-27 m below current datum and drained south towards the Pacific Ocean via the Alsek River. During this period the lake was smaller and, though hydrologically open, the long residence time and nearby sulfate-rich springs led to intermittent meromictic conditions with periodic anoxia in the hypolimnion. Around 1300 Cal. Yr. BP, the Duke River began to flow into the main basin of the lake raising the level by 7-12 m and re-established regular mixing conditions. An abrupt change in sediment character around 430-300 Cal. Yr. BP. indicated a period of complete hydrologic closure after a major advance of Kaskawulsh Glacier that blocked the southerly drainage. The lake rose to 12m above current datum before overtopping the Duke River fan, initiating northward drainage via the Yukon River system. Shortly thereafter the lake fell to the current datum. The isotope hydrology in 2004/5 confirmed the water balance was highly dependent on discharge from the Slims River. Declining glacial meltwater contributions and the abrupt cessation that occurred during 2016 will likely lead to lower lake water levels and a possible return to pre-1300 Cal. Yr. BP. conditions.

Presentation type: Oral Presentation

ES09-05 Late Pliocene and Early Pleistocene glaciation of the tropical Andes

Nicholas J. Roberts[1], René W. Barendregt[2], John J. Clague[1]

[1] Dept. of Earth Sciences, Simon Fraser University, Canada, V5A 1S6
Phone: 782-782-3856 Fax: 778-782-4198, E-mail: nickr@sfu.ca
[2] Dept. of Geography, University of Lethbridge, T1K 6T5

Abstract
Knowledge of late Pliocene and Early Pleistocene glaciation is restricted to globally or regionally averaged records from marine sediments and to sparse terrestrial deposits concentrated in mid-to-high latitudes. We have documented tropical glaciations in the eastern Central Andes spanning at least 1.5 Ma of this period from lithostratigraphy and magnetostratigraphy of six sections exposing sediments beneath the Altiplano Plateau at La Paz, Bolivia. Diamicton units in the sub-Altiplano sequence contain striated and faceted clasts with strong unimodal long-axis fabrics, and are separated by mature soils indicating periods of landscape stability of probably 10^3-10^4 years. A locally extensive volcanic marker bed – the 2.74-Ma Chijini Tuff – and multiple polarity reversals enable correlation between our sections, and three previously reported sections. Sedimentological differences among the sections along an 18-km transect oblique to the Cordillera Real indicate increasing glacier extent over time. The tuff ties the composite polarity sequence to the Geomagnetic Polarity Time Scale, demonstrating that the stratigraphic record extends from the latest Gilbert Chron to the Olduvai subchron or possibly Jaramillo subchron. Due to the dominance of small numbers of cold peaks during some short-duration polarity intervals during that period, some glacial units can be linked to globally cool periods of the astronomically tuned, benthic oxygen isotope (δ18O) record. Most of the late-Pliocene glacial units unambiguously correspond to seven specific marine isotope stages (including MG2, M2, KM2, and G10). In most cases, Pleistocene glacial units can only be constrained to multiple possible cold peaks. The sequence records sixteen glaciations directly before, during, and after the globally warm mid-Piacenzian (3.265-3.025 Ma), and throughout Plio-Pleistocene climate deterioration. Glaciation in the Central Andes preceded the onset of widespread Northern Hemisphere continental glaciation. Good agreement with the best available high-latitude records indicates that glacial events in the southern tropics broadly coincided with those nearer both poles. [300 words]

Presentation type: Oral Presentation

ES09-06 Temporal and spatial patterns of debris flow activity, Hatzic Valley, Lower Mainland BC: implications for geomorphic risk assessment

Pierre Friele[1], James Wetherill[2], Tom Millard[3], Ryan McQueen[3] and John Clague[4]

[1] Cordilleran Geoscience, PO Box 612, Squamish, BC, V8B 0A5
Phone: 604-898-4770 E-mail: pfriele@gmail.com
[2] Braun Geotechnical Ltd., 106A – 9785, 192 Street, Surrey, BC V4N 4C7
[3] BC Ministry of Forests Lands and Natural Resource Operations, West Coast Region, Suite #103 - 2100 Labieux Road, Nanaimo, BC V9T-6E9
[4] Department of Earth Sciences, Simon Fraser University, Burnaby, BC V5A 1S6

Abstract
Residential development in British Columbia is constrained by the availability of suitable land. The easiest lands to develop are valley bottom lands, but because BC is mountainous, these lands are typically vulnerable to hillslope hazards. Hence, provincial legislation requires that lands are assessed for their safety for residential use. This requires hazard characterization, including identification of process domain, probability of the hazard and the partial risk affecting the proposed building site. This paper reports on the disturbance history from a series of watersheds draining Durieu Ridge, Hatzic Valley, Lower Mainland, BC, a rural area subject to increasing development pressure. We compare a deep-time (7000 year) radiocarbon dated stratigraphic record of fan disturbance on a fan draining an unlogged watershed to the historic air photo record (1940-2015) of basin disturbance for a series of watersheds affected by varying levels of forest disturbance including fire and logging. The results indicate that landslide activity and fan disturbance is pulsed, characterised by long periods of stability, allowing for well-developed soil horizons to form, punctuated by periods of instability. In the past, triggers for disturbance are not known, but are likely conditioned by factors such as earthquake, fire, extreme climatic events and Holocene climate change; while historic disturbance appears related to fire and logging activity. These results indicate that hazard assessments cannot rely on shorter-term (less than several thousand years) geomorphic landscape characterisation, but must consider longer-term records, extending back to at least 6-7 thousand years before present, but allowing for the demise of the paraglacial sediment pulse.

Presentation type: Oral Presentation

ES09-07 Radiocarbon constraints on ice sheet cover in northeastern British Columbia

Marten Geertsema[1,3*], John Clague[2], Brian Menounos[3] and Timothy Jull[4]

[1] Province of British Columbia, Prince George BC, BC, V2L 1R5
Phone: 250-561-3473 , E-mail: marten.geertsema@gov.bc.ca
[2] Simon Fraser University
[3] University of Northern British Columbia
[4] Arizona State University

Abstract
We have collected charcoal ages from a series of mudflow fans in the Peace River valley near Fort St. John, British Columbia. We interpret the some of the charcoal to be *in situ*, other charcoal to be detrital, but all to have been produced within the regional catchment. Prior to fan formation, however, other charcoal in the catchments of the fans was deposited in glacial Lake Peace and subsequently reworked and deposited in the fans. The implication of this reasoning, allowing for built-in ages (less than about 200 years in the boreal forest), is that somewhere in the catchment a wildfire occurred at time of the age of the charcoal. We plotted our plotted ages with other published ages from the study area to look for gaps in the record. The youngest substantial gap in radiocarbon ages is between 11,940 $\pm$ 61 ^{14}C yr BP (13,960-13,670 cal yr BP) and 12,556 $\pm$ 73 ^{14}C yr BP (15,100-14,250 cal yr BP). The average and extreme ranges of this gap are, respectively, 950 and 290-1430 cal yrs. This gap is likely too short for ice-sheet placement and, more importantly, is inconsistent with other data. Another, conspicuous gap occurs between 17,830 $\pm$ 110 ^{14}C yr BP (21,500-20,650 cal yr BP and 19,600 $\pm$ 250 ^{14}C yr BP (24,060-22,610 cal yr BP). The average and extreme ranges of this gap are, respectively, 2420 and 1110-3410 cal yrs. If our radiocarbon ages are correct, they constrain the last occupation of Peace River valley near Fort St. John by the Laurentide Ice Sheet to a period of 1110-3410 years between 24,060 and 20,650 years ago.

Presentation type: Oral Presentation

ES09-08 Revising the Tephrostratigraphy of Alberta

Britta J.L. Jensen[1], Alwynne B. Beaudoin[1]

[1] Quaternary Environments, Royal Alberta Museum, Edmonton, AB, T5M 0G6
Phone: 780-493-9192, Email: britta.jensen@gov.ab.ca

Abstract
John has always been good at finding ways to solve smaller, but outstanding, scientific questions that feed into understanding larger problems, particularly in regards to geochronology. Here we apply this ethos of John's and channel his appreciation for all things chronology by revising the tephrostratigraphic framework for Alberta. For decades tephra have played an important role in dating archaeological and stratigraphic sections in Alberta. There are at least three visible Holocene tephra deposits in the province: Mazama, ubiquitous across the lower half of the province, and a Mount St. Helens (MSH) set Y tephra and Bridge River tephra, both primarily in west-central Alberta. These tephra are important stratigraphic markers in a region where radiocarbon dating is bedeviled by carbonate and bitumen, but they have rarely been identified beyond field characteristics and light microscopy. This has resulted in potential misidentifications and uncertainty in tephra-based chronologies, particularly for MSH Y tephra. Is it MSH Yn? Is there an older event present in this region? What is the age of this unit? Using archived collections at the Royal Alberta Museum and revisiting classic sites along the Yellowhead corridor west of Edmonton, we geochemically characterized over 40 tephra, and radiocarbon-dated three sites in order to test the one vs two MSH Y problem. Our results revise the distribution for these tephra, but most importantly, find no evidence of two MSH Y tephra. All samples correlate to MSH Yn, and we provide the first Bayesian age estimate for this unit, the first reassessment of its age since 1990. This is surprising considering it was produced by MSH's largest Holocene eruption, and is proving to be a key mid-Holocene stratigraphic marker across North America. [278 words]

Presentation type: Oral Presentation

ES09-09 Paleoseismic evidence for repeated Holocene displacements along the Denali Fault in southwest Yukon Territory

Andrée Blais-Stevens[1] , John J. Clague[2], Menounos, B.[3], and Brahney, J. [4]

[1] Geological Survey of Canada, 601 Booth Street, Ottawa, ON, K1A 0E8
Phone: 613-947-2787, E-mail: andree.blais-stevens@canada.ca
[2] Department of Earth Sciences, Simon Fraser University, Burnaby, BC, V5A 1A6
[3] University of Northern British Columbia, Department of Geography, Prince George, BC, V6T 1Z9
[4] Utah State University, Department of Watershed Sciences, Logan, Utah, 84322-5200

Abstract
The Yukon-Alaska Highway corridor in southwest Yukon Territory is subject to several geohazards, including landslides and debris flows, floods, permafrost degradation, and earthquakes on faults in the St. Elias Mountains and Shakwak Valley. The Denali Fault is located at the east front of the St. Elias Mountains and extends in a northwesterly direction parallel to the Alaska Highway for a distance of about 190 km. It is one of few confirmed active faults on the land surface of western Canada. Holocene faulting is indicated by a rectilinear series of scarps and mounds cross-cutting late Pleistocene drift, a small offset of a low Holocene terrace on the south side of Duke River, and by tectonically deformed Pleistocene and Holocene sediments exposed in a bluff on the north side of Duke River. We documented Holocene activity along the Denali Fault as part of Natural Resources Canada Program for Research and Development and its Public Safety Geoscience Program. Trenches excavated across fault scarp by the US Geological Survey and Yukon Geological Survey in 2008 and re-examined by Simon Fraser University and the Geological Survey of Canada in 2013 reveal sediment disturbance related to several large earthquakes in the past 6000 years. A nearby pond (Crescent Lake) was impounded against the fault scarp; sediment cores recovered from the lake reveal water-level and sedimentation changes that are likely associated with these earthquakes. The fault also offsets the older and younger White River tephras (*ca*. 1900 and 1200 years old). Stratified Pleistocene outwash gravel outcropping along Duke River has been tilted to the east where crossed by the fault, and many stones within the gravel have been fractured and displaced by movement along the fault. The uppermost outwash gravel at Duke River also displays a cross-section of a positive flower structure (mound), indicative of Holocene contraction of the sediments.

Presentation type: Oral Presentation

ES09-10 Showdown at the border: revisiting the long-standing Sumas controversy across the 49th Parallel

Douglas H. Clark[1]

[1] Geology Dept., Western Washington University, Bellingham, WA, 98225-9080, USA; 360-650-3581, email: doug.clark@wwu.edu

Abstract

Over his long and distinguished career, John Clague has had a flair for finding (and occasionally inciting) geologic controversies. One of the most enduring of those disputes involves the timing and nature of the Sumas stade, the final Pleistocene advance of the Cordilleran Ice Sheet into the Fraser Lowland. Canadian geologists, lead by John, have argued that this event involved two main advances into the border region, both preceding the Younger Dryas Chronozone (i.e., before ca. 13,100 cal yr BP). Conversely, workers south of the border, lead by Easterbrook, have contended that the Sumas comprised four phases, all occurring after ~13,400 cal yr BP and largely overlapping the YD. New dating, stratigraphic constraints, and lidar data suggest a possible resolution to this long-standing and contentious disagreement, and provide a possible mechanism to explain, in part, the timing of the event. New basal 14C dates from lakes formed immediately beyond the outermost Sumas moraines indicate that the event comprised at least two major advances, with an early maximum at ~14,500 cal yr BP and a second advance after ~14,200 cal yr BP. Subsequent retreat began before ~13,050 cal yr BP. Reassessment of the stratigraphic constraints of Easterbrook in light of the lidar data suggest that many dates previously considered to be maximum limits are actually direct ages or minima. A final YD-related advance may also have occurred, though. Interleaved Sumas moraines and marine strandlines imaged in lidar indicate that the second Sumas advance and retreat coincided in part with rapid local sea level rise and fall, respectively. These changes may relate to effects of Meltwater Pulse 1a superimposed on rapid isostatic rebound, in turn suggesting a possible dynamic link between the Sumas and sea level. Taken together, these new findings are largely consistent with Clague's original interpretation for the Sumas event. [300 words]

Presentation type: Oral Presentation

ES09-11 The catastrophic Flims landslide and associated Bonaduz gravel, Vorderrhein River Valley, Switzerland

Nancy Calhoun, John J. Clague[2], and Andreas von Poschinger[3]

[1] Oregon Department of Geology and Mineral Industries; 800 NE Oregon St, Portland, Oregon, USA 97214
Phone: (360)820-1530 E-mail: nancyccalhoun@gmail.com
[2] Emeritus, Simon Fraser University, Burnaby, BC, Canada, V5A-1S6
[3] Bavarian Environmental Agency, D-86179 Augsburg, Germany

Abstract
About 9400 years ago, in the Vorderrhein valley of the eastern Swiss Alps, the Flims landslide failed catastrophically, with 10-12 km^3 of valley wall impacting the valley below. The Flims landslide mobilised over 1 km^3 of valley-fill sediments, sending a slurry over ten kilometers downstream. The mass flow split into two tongues, with one tongue flowing up a tributary, the Hinterrhein River valley, at a right angle to the main trunk valley. The Bonaduz gravel, as it is referred to, is found in near vertical faces and is at least 65 m thick, grading from coarse cobbley sandy gravel at the base to silty very coarse sand at the top. Seeing new aspects to a convoluted geomorphic and sedimentologic setting is like seeing John Clague digging a hole: he is in his element. On many occasions since initial fieldwork related to the Flims landslide, John has endeavored to get back to the field for another consideration, another scramble for sites, and another hole dug to further any evidence related to the Bonaduz mass flow, despite the field site's location in far-away rural Switzerland. John Clague's persistence is outpaced only by his unquenchable curiosity; it was an honour and privilege to ponder and piece together the catastrophic events of the Flims landslide and Bonaduz gravel mass flow with John.
[219 words]

Presentation type: Poster

ES09-12 From the Halls of Simon Fraser to the Shores of Lake Concrete: Applying the Clague Method to Skagit Valley, Washington and British Columbia

Jon L. Riedel

Phone: 360-854-7330; email: jon_riedel@nps.gov

In 2000 I enrolled as a graduate student at Simon Fraser University and began to work with John Clague. Through many field trips and a few classes I learned a great deal about reading Quaternary stratigraphy and understanding glacial landscapes. The 'Clague Method' was thus applied to answer several intriguing questions about the Quaternary history of Skagit valley. Our first publication focused on the glacial rearrangement of the Skagit drainage pattern. Pro-glacial lakes dammed in North Cascade valleys by the south-flowing Cordilleran Ice Sheet spilled across and eliminated regional hydrologic divides, leading to the reorganization of the Skagit watershed and the joining of the Skagit with the Fraser and Okanagan valleys. This model of ice sheet drainage rearrangement could help explain the unusual drainage pattern of the Fraser River and other Coast Mountain streams. Another publication investigated the alpine glacial history during the last glaciation. Along with Brent Ward, we examined lacustrine beds exposed along the Skagit River at four main sites that recorded the existence of ice-dammed glacial lakes Skymo and Concrete. Abundant organic deposits allowed us to obtain the first radiometric control on the beginning of the Evans Creek stade (MIS2) in the Cascades and to refine the regional chronology of alpine glaciation from 30-20ka. One of my most memorable endeavors as a scientist was the investigation of the Holocene glacial history of Mt. Baker with John and the so called 'BBBB' team. For several summers we hiked up the valleys to glacial fore-fields looking for buried wood and volcanic tephra. The buried wood record turned out to be remarkable, and we were able to bracket the ages of multiple glacial advances over 6ka. A 2012 publication presented conclusive evidence that late glacial and early Holocene glacial advances on Mt. Baker were smaller than previously believed.

Presentation type: Oral

ES09-13 Development and maintenance of the fluted cliffs of the Na Pali coast, Kauai, Hawaiian Islands

Gerald Osborn[1*], Kaylee Norsworthy[1], and Chuck Blay[2]

[1] Geoscience Dept., University of Calgary, Calgary, Alberta, T2N 1N4
Phone: 403-270-7857 E-mail: osborn@ucalgary.ca
[2] Teok Investigations, Koloa, Kauai, HI 96756

Abstract
The deeply grooved ("fluted") escarpment along the Na Pali coast on the NW side of Kauai is one of the most dramatic geomorphic features on planet Earth. Its spectacular character arises from its height and superimposed nearly parallel, very steep (45-80°), wide (30-100m), and deep gullies, eroded by runoff, and separated by sharp divides. Although there are small rockslide scars on the cliffs, and wave-induced rockfall right at the coastline, the fluted cliffs are not significantly sculpted by mass movement. Rocks strong enough to stand as steep 600 m cliffs without failing generally are not significantly erodible by runoff, which is why Hawaiian cliffs are unusual. Erodibility is a consequence of chemical weathering of the thin-bedded Na Pali Formation basalts. Proxy evidence suggests that rotten basalts and clay weathering products are a few tens of meters deep. Decomposition of basalt must proceed downward at the about the same rate as removal of mass by erosion. The fluted cliffs retreat parallel to themselves because as much material is eroded at the bases of gullies as higher up, and because no debris collects at the bases of gullies. Erosion proceeds by episodic removal of thin sheets of weathering products. Below the very steep fluted cliffs are slopes with lesser gradients (30-45˚). Conceivably these lower slopes are developed on a lower unit of Na Pali basalts that behaves mechanically differently than an upper unit. But no such lithologic difference has been described or is obvious. A tentative hypothesis is that the lower slopes are a footslope left behind as the fluted cliffs retreat parallel to themselves. Parallel retreat of slopes and production of basal footslopes are traditionally regarded as processes associated with desert environments, but Hawaiian examples indicate they can occur even in tropical environments.

Presentation type: Oral

ES09-14 A research – policy connection to reduce urban disaster losses: Risk-based land use

Lambertus C. Struik[1,2] and Laurie D. Pearce[3]

[1] Simon Fraser University, Burnaby, BC, V5A 1S6
Phone: 236-888-5203, E-mail: lstruik@sfu.ca
[2]Geological Survey of Canada, Vancouver, BC, V6B 5J2
[3]Justice Institute of British Columbia, New Westminster, BC, V3L 5T4
Phone: 604.528.5848, E-mail: lpearce@jibc.ca

Abstract
John Clague recognizes the value of intimately connected research and policy, and catalyzes that connection to reduce natural disaster losses. We review a recent connection John fostered in risk-based land-use decision making, which demonstrates elements of his influence. The risk-based land-use guide for Metro-Vancouver, British Columbia was created to strengthen community safety and resilience by supporting informed land-use decisions. The audience for the guide includes municipal and regional officials, because they are responsible for strategic and operational land-use recommendations and decisions. Over five years, these officials contributed to creating the land-use guide and their input was used to ensure practicality and relevance. The guide demonstrates how to measure and understand the hazard-based risk of existing and proposed land-use. It explains how to use existing municipal tools and processes to achieve and maintain acceptable levels of risk; defines hazard and risk concepts and provides a number of examples. The guide is based on a short list of principles considered effective for risk management. Those principles emphasize that effective risk management is achieved through open and transparent sharing of knowledge by citizens, developers, municipal and regional staff and elected officials. The principles also state that risk management requires a clear division and sharing of responsibility. A new land-use risk management scheme came out of creating the guide. The scheme compares to the ISO/CSA 31000 risk management standard, but instead uses hazard and land-use familiar language and sequencing. The land-use risk-management scheme emphasizes the need to decide what is important for the community to keep safe and determine its acceptable risk levels. It clearly separates measuring hazard potential, exposure to each hazard, and vulnerability to each hazard. The design covers all hazards that can affect land, people and infrastructure and continues to evolve and become nationalized. [293 words]

Presentation type: Oral Presentation

ES09-15 Effects of landslide and flood-induced sediment pulses on the geomorphology of the Upper Lillooet River Valley

Carie-Ann Lau[1*], Caterina Zei[2], John Clague[1], Brent Ward[1], Marco Giardino[2], Natalie Vogt[3], Brian Menonous[4], Hazel Wong[5], and Allison Westin[1]

[1] Department of Earth Sciences., Simon Fraser University, Burnaby, BC, V5A 1S6
Phone: 778-782-4564 Fax: 778-321-1234, E-mail: carieann_lau@sfu.ca
[2] Dipartimento di Scienze della Terra., Università Torino, Torino, Italy, 10125
[3] University of Alberta, Edmonton, AB, T6G 2R3
[4] Department of Geography, University of Northern British Columbia, Prince George, BC, V2N 4Z9
[5] Golder Associates., Vancouver, BC, V5M 4X3

Abstract

The August 6th, 2010 Mount Meager 50 M m^3 rock avalanche-debris flow is one of the largest landslides in Canadian history. The debris overwhelmed a large area of the Lillooet River floodplain and temporarily dammed Meager Creek. The river has slowly flushed large volumes of sediment downstream from the deposit through the aggrading, wandering reaches and distally to Lillooet Lake. In response to this sediment pulse, the upper river floodplain has widened, severely eroded the forestry road network, and deposited large sand and gravel bars. Sediment was mostly moved during flood events, such as the rain-on-snow event two months after the landslide. We also examined the historical record of previous Mount Meager landslides and Lillooet River flooding events with structure-from-motion models developed from historical air photos. Historically, the river has laterally migrated nearly a kilometre across the valley floor in response to floods and sediment pulses. Geochemical analysis was also used to identify Mount Meager sediment sources and determine its relative contribution to Lillooet Lake from 1623 to 1992.

This project has been a long-time passion for John Clague and he has mentored numerous undergraduate and graduate students during its course. We honour him by finally giving a talk about it. One can draw multiple parallels to being mentored by John and sediment pulses: initially the system is totally overwhelmed, questions are raised, and space is made to accommodate the change. Eventually the system matures to accommodate the gained matter and is permanently raised to a new level.

[247 words]

Presentation type: Oral Presentation

ES09-16 Evolution of Fraser Canyon, British Columbia, Canada

Brian Menounos [*1], Jeremy Venditti[2], Eva Kwoll[2], John J. Clague[3], Michael Church[4] Brent Goehring[5]

[1] Geography Program and Natural Resources and Environmental Studies Institute, University of Northern British Columbia, Prince George, BC, V2N 4Z9, Email: Menounos@unbc.ca
[2]Dept. of Geography, Simon Fraser University, Burnaby, BC, V5A 1S6
[3]Dept. of Earth Sciences, Simon Fraser University, Burnaby, BC, V5A 1S6
[4]Dept. of Geography, University of British Columbia, V6T 1Z2
[5]Dept. of Earth and Environmental Sciences, Tulane University, New Orleans, LA. 70118

Abstract
The relative importance of fluvial and glacial processes in shaping montane environments continues to be debated. Part of the difficulty in quantifying the erosional efficiency of these processes is the interplay of glacial and fluvial events. A germane example that illustrates this interplay is Fraser River. At times during the Pleistocene, its 234,000 km^2 watershed was covered or partly covered by glaciers, whereas at others the watershed was largely ice-free and fluvial processes dominated. The Fraser River Canyon is a geographical region along the Fraser River where the river crosses the Interior Plateau of British Columbia and flows along a fault zone between the Coast and Cascade mountain ranges. The Canyon is characterized by a series of 45 deep narrow bedrock canyons within a larger broader valley. Previous work suggests that much of the present Fraser River watershed drained to the north and east until ~1.06 Ma. A smaller south-flowing river occupied the present-day Fraser Canyon. Only in the past million years has the entire watershed supplied the river that now flows through the canyon. The morphology of Fraser Canyon is typical of deeply incised bedrock rivers in unglaciated areas, yet the canyon was repeatedly glaciated after 1.06 Ma. Our on-going research program utilizes newly acquired LiDAR imagery, numerical modeling, and terrestrial cosmogenic nuclide dating to unravel the geologic history of the canyon and the relative roles of glacial and fluvial processes in shaping it. Our results have important implications for understanding the relative contribution of glacial and fluvial erosion in formerly glaciated terrain and for understanding the frequency and magnitude of geomorphic events in determining landscape form.

Presentation type: **Oral Presentation**

ES09-17 The end of the Pleistocene in the northern Cordillera and the importance of Allerod warming on rapid ecosystem changes

Duane Froese

Dept. of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta T6G 2E3
Phone: 780-492-1968; E-mail: duane.froese@ualberta.ca

Abstract
One of the most enduring contributions of John Clague's remarkable career has been the development of the Quaternary record of western Canada. In this talk, I speak to some of the contributions of John's regional perspective over nearly 50 years of work in western Canada, and his careful consideration of the importance stratigraphy and development of robust chronologies for sea level studies, natural hazards, recent glacier changes, paleoenvironmental records, tephras, and the Cordilleran Ice Sheet. Over the last ~20 years or so, my group and collaborators, including several former students of John's, have taken a similar approach to the regional record of past glaciation and interglaciation, and development of chronologies for regional environmental change in the nonglaciated region of Yukon and Alaska. Here I focus on the rapid warming during the latest Pleistocene, broadly correlative with the Allerod interval and show through diverse records the impacts of this warming on permafrost, vegetation and the catastrophic losses of Pleistocene megafauna.

Presentation type: Oral Presentation- Invited Keynote

ES09-18 Glacier fluctuations, ice-dammed lakes, and regional hydrology: John Clague's geological crystal ball in the St. Elias Mountains

Alberto V. Reyes[1]

[1] Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, T5N 1T4
Phone: 780-492-8171, E-mail: areyes@ualberta.ca

Abstract
John Clague's first paper, on the magnitude of jökulhlaups, foreshadowed a career-long interest and ~20 published papers on the processes, sedimentary records, geomorphic legacy, and hazard implications of glacier-lake interactions. An early focus of John's research on this theme was the St. Elias Mountains of southwest Yukon, where some large valley glaciers repeatedly surged across trunk valleys during intervals of late Holocene glacier expansion, impounding large lakes that sometimes drained catastrophically. Tree-ring dating techniques, coupled with millennial-length regional ring-width chronologies, allow refined understanding of formation of these large ice-dammed lakes in the Alsek and Donjek river valleys that complements John's pioneering work in the region. At Kaskawulsh Glacier and Kluane Lake, an integrated campaign of tree-ring dating on glacially-sheared trees, drowned forests, and driftwood strandlines, together with gochemical studies of Kluane Lake sediments, demonstrated clearly that climate change and glacier fluctuations had profound impacts on regional hydrology on millennial-to-decadal timescales. John's careful and multidisciplinary field studies of glacier-lake interactions in the St. Elias Mountains included the 2006 prediction that Kaskawulsh River would eventually capture drainage of Kaskawulsh Glacier from Slims River and Kluane Lake, a major regional hydrological event that occurred abruptly near the start of the 2016 meltwater season and portends potentially dramatic ecological and landscape impacts in the region. [211 words]

Presentation type: Oral Presentation

ES09-19 Applications of InSAR ground deformation measurements in southern British Columbia

Giacomo Falorni[1], Leila Ertolahti, Gioachino Roberti[2], Brent Ward[3], Jean Pascal Iannacone[1] Geidy Baldeon[1] and John Clague[3]

[1] TRE Altamira Inc, 410-475 W Georgia St, Vancouver, BC, 46B 4M9
Phone: 604-331-2512, E-mail: giacomo.falorni@tre-altamira.com
[2] Université Blaise Pascal, France
[3] Dept. of Earth Sciences, Simon Fraser Univ., Burnaby, BC, V5A 1S6

Abstract
InSAR is a technique for extracting ground deformation information from radar satellite data. It is used to study surface movement induced by mining, oil and gas, infrastructure construction, tunneling, groundwater extraction, volcanic activity, earthquakes and other natural or anthropogenic processes. In the Vancouver metropolitan area it has been used to investigate localized higher rates of settlement stemming from anthropogenic sources, notably the application of loads in construction. The induced ground movement is a structural and engineering concern. Long term subsidence has also been investigated as much of the Fraser delta plain is at or below mean sea level and may be at increasing risk of flooding when considering long-term sea-level rise. Another natural hazard in southern BC regards the Mount Meager strato-volcano massif in the Northern Cascade Volcanic Arc. An international research project is studying the stability of Mt Meager. InSAR data is used to observe slope deformation prior to the 2010 failure and to identify and monitor other unstable slopes that could potentially evolve into future catastrophic collapses, with consequent risk for the local communities located downstream from the volcano. John Clague was the catalyst for much of this work, some of the results of which will be shown here. [201 words]

Presentation type: Oral Presentation

ES09-20 The Timing and Character of Postglacial Fluvial Incision, Fraser River Valley, South-central British Columbia

Olav B. Lian[1]

[1]Department of Geography and the Environment, University of the Fraser Valley, 33844 King Road, Abbotsford B.C., V2V 7M8, olav.lian@ufv.ca

Abstract
During the last glaciation, the Fraser River valley was filled with several hundred metres of sediments. Following deglaciation, ancestral Fraser River incised this sediment fill, leaving a series of terraces capped with 5–10 metres of fluvial gravel that are overlain by several metres of paraglacial fan sediment which is, in turn, capped by several metres of aeolian silt and sand. A lack of preserved organic material for radiocarbon dating in these sediments has made understanding the timing postglacial fluvial incision and terrace formation difficult. Optical dating of fluvial and aeolian sand extracted from terrace tops provides an alternative means of providing a chronology. Experiments using feldspar collected from aeolian units for which their age is well defined by tephra indicates that this mineral is the best chronometer in the region, but that quartz may also be viable. Using quartz and feldspar sand and both multiple-aliquot and single-aliquot regenerative dose (SAR) laboratory protocols, it can be shown that by 12 ka (calendar years) incision of ancestral Fraser River in south-central British Columbia was well on its way, and sometime after 6 ka, but before 4 ka, the Fraser River had nearly reached its current position.

Presentation type: Oral Presentation

The "geoNatHaz" experience and the enhancement of international Earth science competence in natural hazards and risks

Marco Giardino[1, 2], Luigi Perotti[1], John Clague[3, 4], Brent Ward[3]
[1] Dipartimento di Scienze della Terra, Università Torino, Torino, Italy, 10125
Phone: +31-011-6705164 Fax: +31-011-6705146, e-mail: marco.giardino@unito.it
[2] NatRisk Research Centre, Università di Torino, Torino, Italy, 10125
[3] Department of Earth Sciences, Simon Fraser University, Burnaby, BC, V5A 1S6
[4] Centre for Natural Hazard Research, Simon Fraser University, Burnaby, BC, V5A 1S6

Abstract
The EU-Canada "geoNatHaz" partnership improves knowledge and skills required to assess and manage natural hazards in mountain regions. Simon Fraser University (Canada) and Università degli studi di Torino (Italy) are leaders of the consortium. Partners include the University of British Columbia, Queen's University, Università di Bologna, Université de Savoie, and the University of Athens.

The geoNatHaz project promotes cross-cultural understanding and internationalization of university natural hazard curricula through common lectures, laboratory exercises, and field activities. Fifty graduate students from the seven Canadian and European partner universities benefited from the project since its establishment. Some students spent up to five months at the

partner universities, taking courses and participating in research teams under the direction of project scientists. Other students engaged in short-term (four-week) exchanges involving training in classic natural hazard case-studies in mountain regions of Canada and Europe. Supporting organizations (government departments and agencies, non-profit organizations and private companies offered internships and technical and scientific support. Exchanges of faculty and technicians ensured that students' educational experiences were challenging, rich, and intellectually rewarding.

The centrepiece of the project were six field courses -three in Europe and three in Canada- whose topics included: (1) impacts of climate change on natural hazards in high mountains, (2) deep-seated rock-slope deformation, (3) mitigation of landslide hazards in mountain valleys, (4) applications of new technologies in natural hazard research, (5) frequency-magnitude relations and risk assessment, and (6) earthquake hazards and risk in mountain regions.

Thanks to the passion and scientific guidance of John Clague, the "geoNatHaz" partnership successfully developed educational activities and catalyzed collaborations among scientists participating in the project, thus promoting up-to-date approaches to natural hazard and risks.

Presentation type: Oral Presentation

Preferred Session: ES09 – In honour of John Clague, one of Canada's foremost Earth Scientists

Is there a link between Glaciation and Volcanism in British Columbia?

Catherine J. Hickson, Tuya Terra Geo Corp., 1503 – 4194 Maywood Street, Burnaby, BC, V5H 4E9, Canada ttgeo@telus.net +1 604 761 5573

The understanding of subglacial volcanism has a strong foundation in British Columbia. In fact, the physiographic name for a flat-topped, subglacial volcano, comes from the Tuya-Teslin region of northwestern British Columbia – Tuya Butte. W.H. Mathews published his seminal paper in 1947 entitled *"Tuyas," flat-topped volcanoes in northern BC*. Since then, there have been many subglacial volcanoes identified showing a wide range of morphology, but all linked by the association of quenched tephras, hyaloclatite, pillow breccias, pillow lavas, and lava flows. The lava flows show variable sizes of columnar jointing, with very small joints, often forming vertical faces where the lava has cooled in direct contract with massive ice. Because of these unique features, the depth of enclosing ice and water can be ascertained from the size, distribution, stratigraphy, and morphology of subglacial volcanoes. Work carried out in the Wells Gray – Clearwater volcanic field (WGCVF) suggests at least four regionally significant periods marked by thick accumulations of ice occurred during the past three million years of earth history as recorded by volcanism in the WGCVF. Volcanism in the region is thought to be connected with deep faulting associated with a transition from the crustal-scale transform-fault dominated tectonics to the north of Wells Gray and the extensional dominated tectonics to the south. The triggering mechanism for the apparently episodic volcanic flare-ups within the WGCVF is unknown. However, in 1974 E.W. Grove proposed that deglaciation might be a possible triggering mechanism. This idea has never been adequately studied as the age-relationships between volcanism

and glacial loading and unloading events remains poorly defined. Additionally, the role of erosion though ice passage, late glacial mega-floods and slope instability of poorly consolidated volcanic deposits has not been studied in detail in British Columbia. The relationship between volcanism and deglaciation remains an enigma worthy of further study.

Submitted for Session ES09: In honour of John Clague, one of Canada's foremost Earth Scientists

A Late Pleistocene stratigraphic record from geotechnical drilling, Evergreen Line Tunnel, Greater Vancouver, BC

Lionel E. Jackson Jr.[1] and Brent C. Ward[1]

[1] Department of Earth Sciences, Simon Fraser University, Burnaby, BC, V5A 1S6

Phone: 778-999-5684 E-mail: lionelj@sfu.ca

Abstract

Drilling logs and detailed study of cores from the construction of a 2 km tunnel (part of the 11 km Evergreen Extension to the metro Vancouver's Sky Train system) have yielded insight into the glacial stratigraphy and paleogeography of SW BC. Although Paleogene sedimentary rock forms uplands to the east and west, the tunnel route lies within more than 140 m of sedimentary fill within a paleo-valley. Its floor lies 30 m or more below sea level. The Evergreen Line Project gave the authors access to bore-hole drilling logs and reports carried out prior to construction and the tunnel contractor, SNC Lavalin Group Inc. (SNCL) contributed four-inch sonic drill cores drilled during tunnel construction for detailed study and sampling. These extended to depths of up to 45 m. Study of the SNCL cores permitted correlation to and interpretation of the earlier, deeper boring logs. Three tills and related glacial fluvial, glaciolacustrine and glacial marine sediments were identified in the SNCL cores as well as organic deposits. Eight radiocarbon ages determined on organic deposits range from 18 ka to > 50 ka. This record can be related to the previously established Coquitlam and Vashon stades of the Fraser Glaciation (MIS 2), the Coquitlam/Vashon Port Moody interstade (ca. 18 ka), the Olympia Interglacial (MIS 3) and the penultimate glaciation (pre-50 ka and suspected to be MIS 4). Each glacial advance was marked by a coarsening upward sequence culminating with coarse ice-proximal gravel and diamicton and the glaciotectonization of underlying sediments. The onset of each glacial cycle resulted in a substantial rise of relative sea level. They were followed by distal glacial marine and subaerial sedimentation. Correlation with deeper boring logs suggests that a much longer record of similar glacial cycles occurs within this fill.

Presentation type: Oral Presentation

Preferred Session: ES09: In honour of John Clague, one of Canada's foremost Earth Scientists