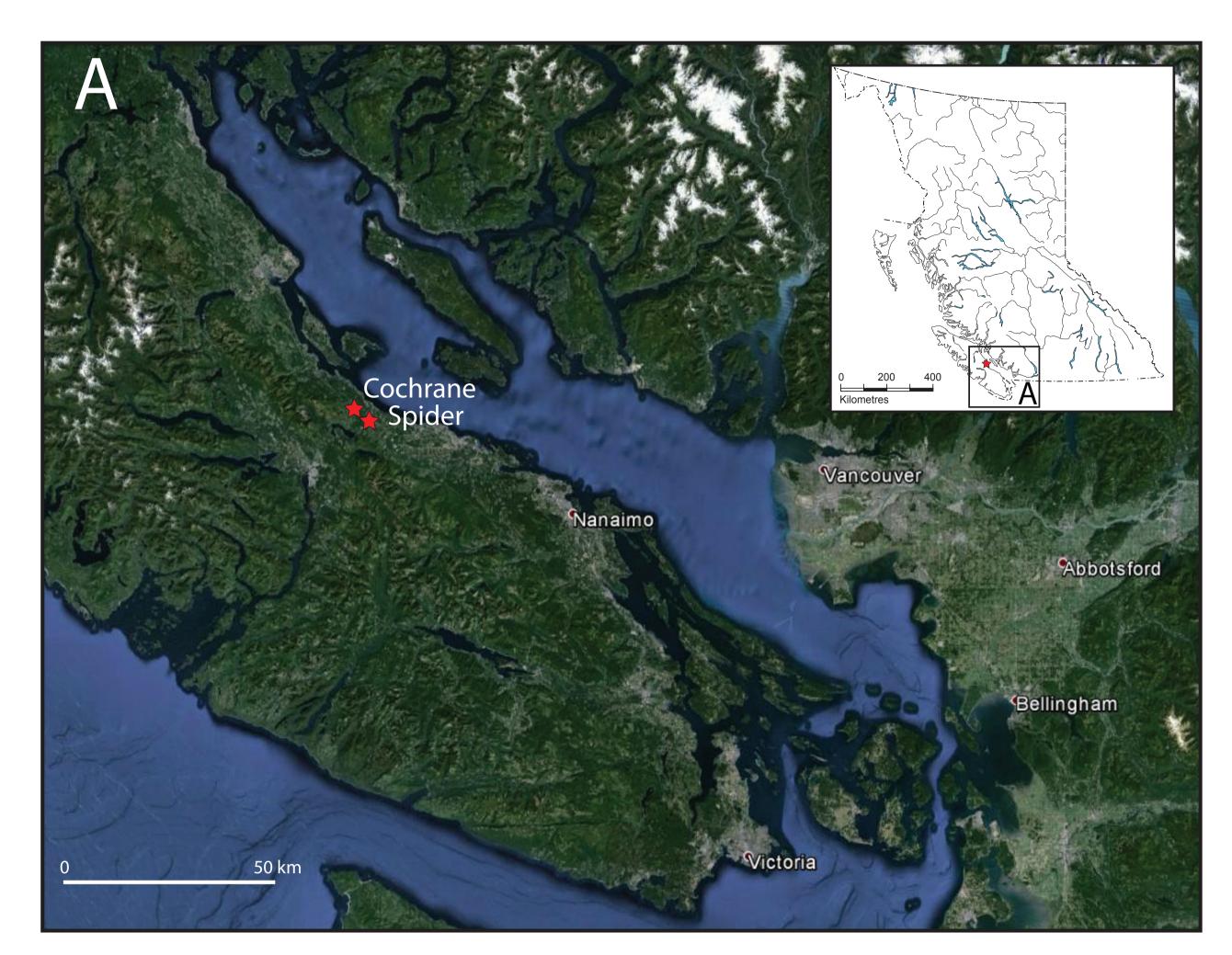
Geological Survey of Canada Scientific Presentation 52

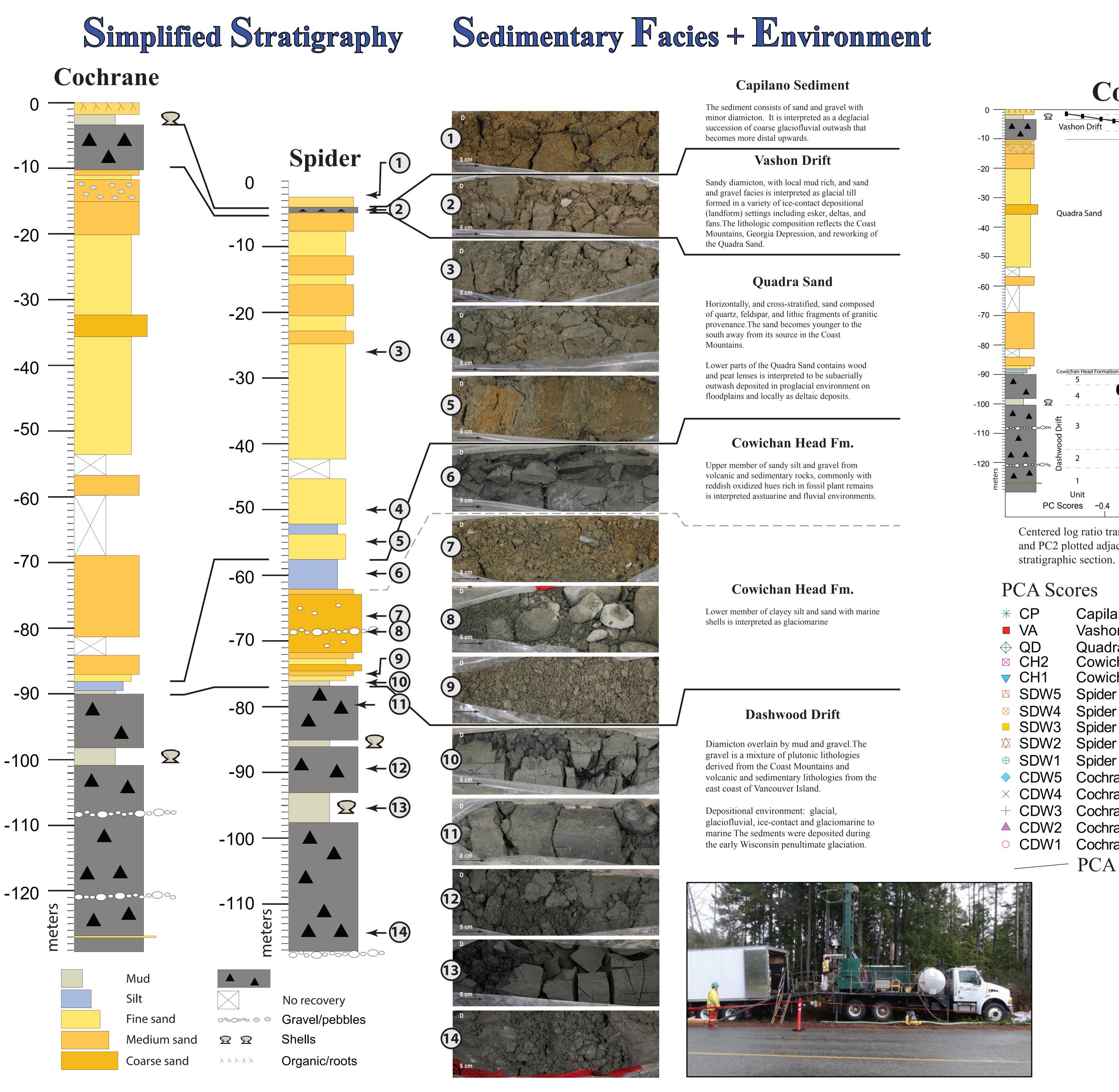
Natural Resources Ressources naturelles Canada Canada

Introduction

A relatively thick and extensive succession of late Pleistocene proglacial, glacial and interstadial sediments occurs in the Strait of Georgia in British Columbia (and Puget Sound in Washington). Strata include the Dashwood and Vashon tills, the Cowichan Head, Quadra sand, and Capilano sediments. All of these units form either regional aquifers, or aquitards, hence understanding the spatial heterogeneity and lithochemistry are of high interest due to increasing groundwater issues in this area. Numerous studies have reviewed the lithostratigraphy, depositional environments and age relationship of these units; however, to-date there has been no systematic geochemical characterization. To resolve this knowledge gap the Geological Survey of Canada in collaboration with the Regional District of Nanaimo, British Columbia, has completed a chemostratigraphic study of 2 boreholes (~130 m deep) approximately 20 km apart, using a portable X-ray fluorescence spectrometer and multivariate statistical methods.

Results from the 234 analyses of the $<63 \mu m$ (silt + clay) size fraction identify 15 elements that document the stratigraphic chemical variability. In the Dashwood till changes in both single element concentrations and multi-element associations indicate local variability within these sediments. The overlying lower Cowichan Head Formation displays similar elemental concentration trends as the underlying Dashwood till and is attributed to sediments sourced from Vancouver Island. In contrast, the upper Cowichan Head Formation and overlying Quadra sand have a geochemical signature (e.g. a relative increase in Sr concentration) reflecting a change in provenance to the Coast Mountains. The overlying Vashon Drift and Capilano Sediments can be differentiated from each other and the underlying Quadra Sand, by variations in the relative enrichment/depletion of the elements Ba, Fe, and Mg. To our knowledge these results are the first systematic geochemical characterization of late Pleistocene succession in the Nanaimo Lowlands.





PORTABLE XRF CHEMOSTRATIGRAPHY OF A PALEO-GLACIAL FORELAND BASIN, THE NANAIMO LOWLANDS, VANCOUVER ISLAND, BRITISH COLUMBIA

R.D. Knight¹, J.M. Bednarski², E. Grunsky³, H.A.J. Russell¹

Location

Methods

- 1) Sample at ~ 1 meter intervals and above and below visible geological
- 2) Dry and disaggregate sample
- 3) Sieve to $<63 \mu m (silt + clay)$
- 4) Place sample in 23 mm diameter plastic vials, to a height of 30 mm, to obtain sufficient density and "infinite thickness"
- 5) Seal vials with 4 μ m thick Chemplex Prolene
- 6) Analyzed sample using Thermo Scientific, Niton XL3t GOLDD
- spectrometer in Soil mode with a 60 second dwell time per filter Insert a Teflon and silica blank, plus multiple CRM's, at the beginning and end of every session and after every10 samples

Knight, R.D., Kjarsgaard, B.A., Plourde, A.P., and Moroz, M., 2013. Portable XRF spectrometry of reference materials with espect to precision, accuracy, instrument drift, dwell time optimization, and calibration; Geological Survey of Canada, Open File 7358 doi:10.4095/292370

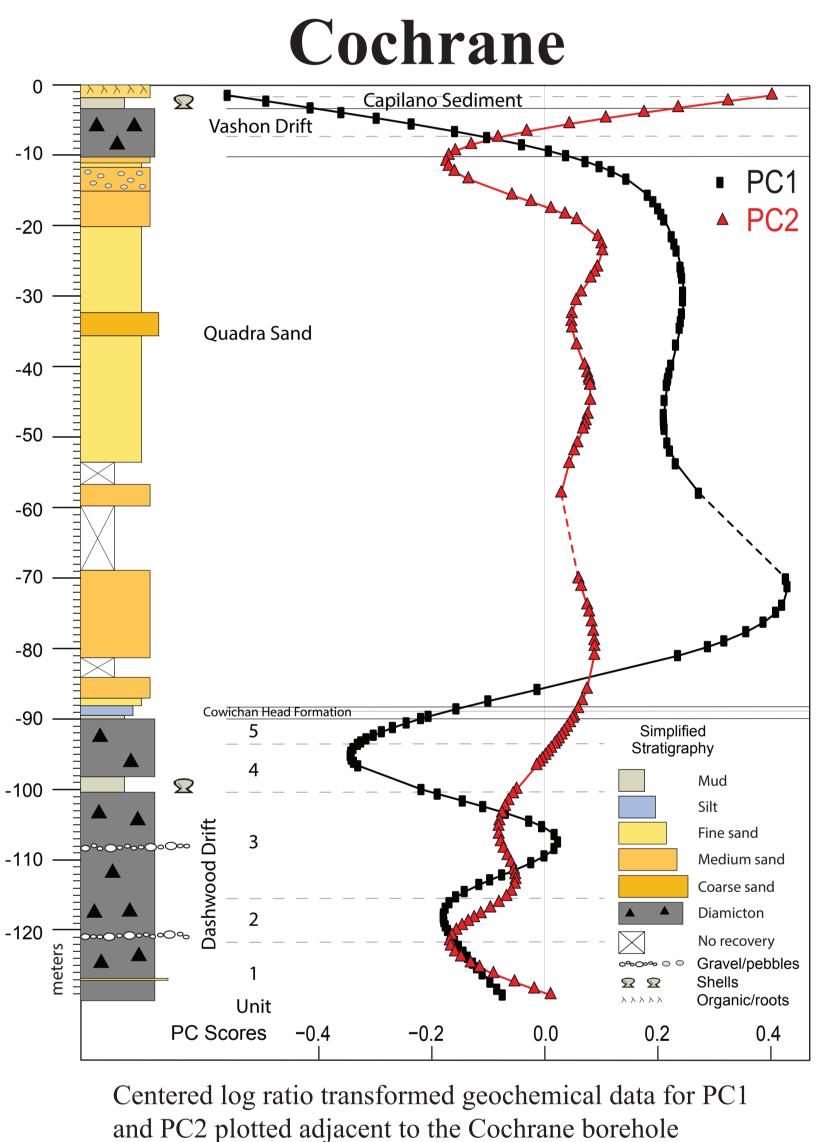
Principal Component Analysis

Comparing the score and loading plots identifies co-relationships between elements and positive and negative relationships of the elements. The relative change of these values and their trends display the behavior of the weighted grouping of elements (i.e. a change in the trend displays a change in the relationship of elements at that depth). Use of principal components can reveal relationships between elements that are co-related and most likely represent a variation in lithology and provenance of the sediments.

Quadra Sand

upper

Spider



PCA Scores

K	CP	Capilano sediments
	VA	Vashon drift
\geq	QD	Quadra sand
\leq	CH2	Cowichan Head Fm.
7	CH1	Cowichan Head Fm.
7	SDW5	Spider Dashwood drift 5
ð	SDW4	Spider Dashwood drift 4
	SDW3	Spider Dashwood drift 3
χ	SDW2	Spider Dashwood drift 2
Ð	SDW1	Spider Dashwood drift 1
	CDW5	Cochrane Dashwood drift 5
<	CDW4	Cochrane Dashwood drift 4
	CDW3	Cochrane Dashwood drift 3
	CDW2	Cochrane Dashwood drift 2
\mathbf{C}	CDW1	Cochrane Dashwood drift 1
		PCA Loading

Principal component loading and scores for PC 1 and PC 2. Elements of similar relationship are plotted as a positive correlation while elements with an opposite relationship plot as a negative correlation.

-0.05 0.00 0.05 0.10 0.15

Centered log ratio transformed geochemical data for PC1,

PC2 and PC3 plotted adjacent to the Spider borehole

-0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 PC3

• PC2

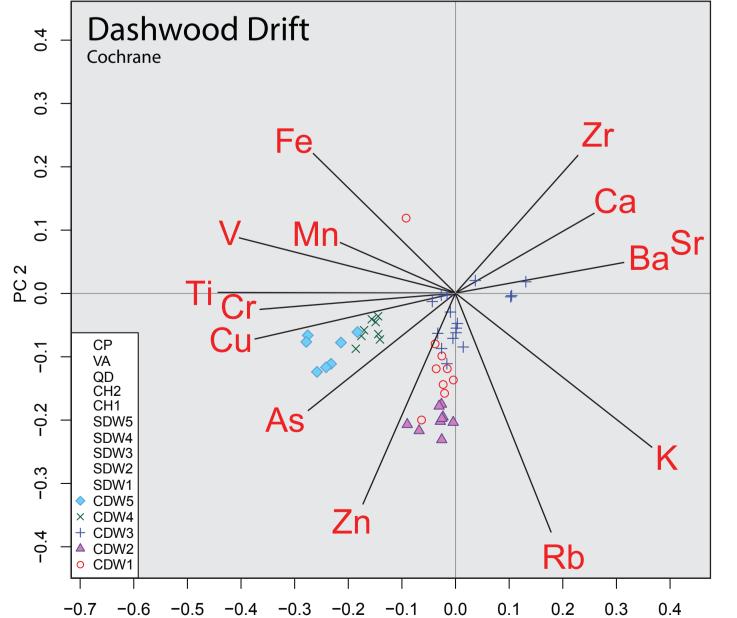
 \bullet PC3

Coarse sand

No recovery

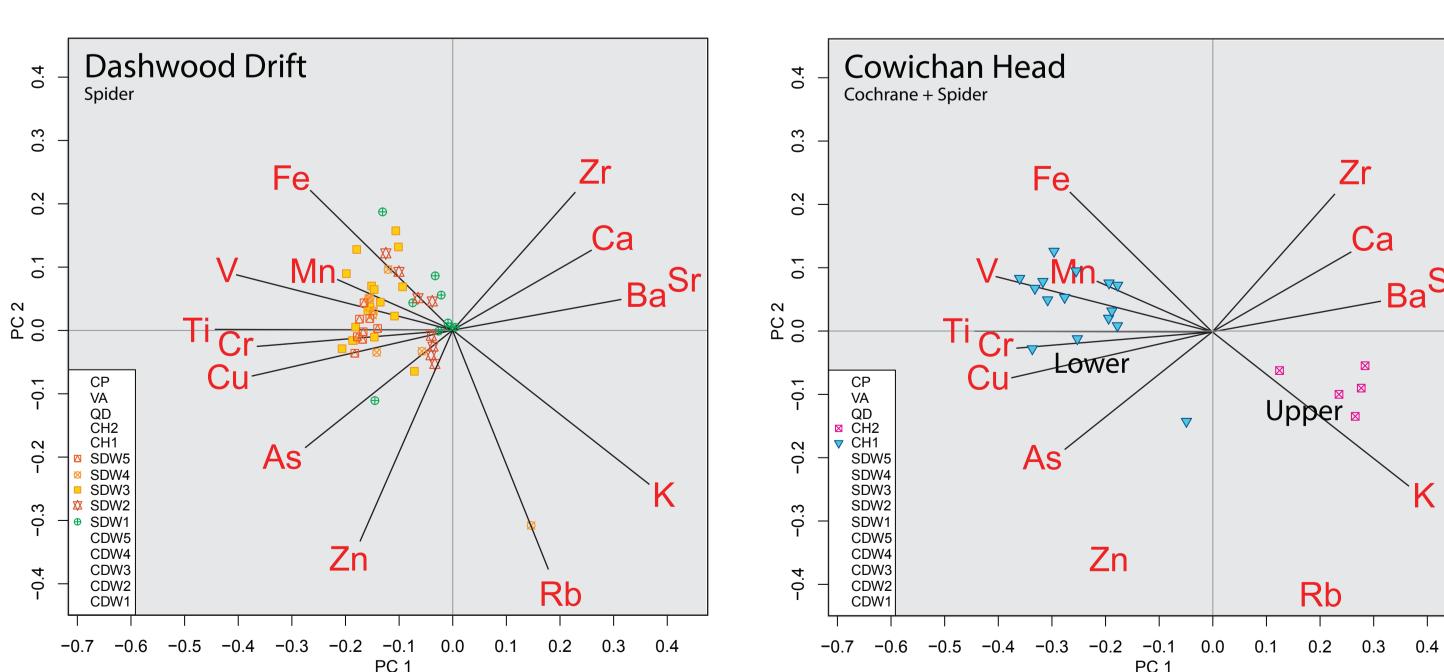
Gravel/pebbles

▲ Diamicton



stratigraphic section.

PC 1 Most units of the Dashwood drift for Cochrane display clumping populations suggesting localized variability in provenance. The populations occupy an area of both - PC1 and PC 2. These sediments display a mixture of plutonic lithologies derived from the Coast Mountains and volcanic and sedimentary lithologies from the east coast of Vancouver

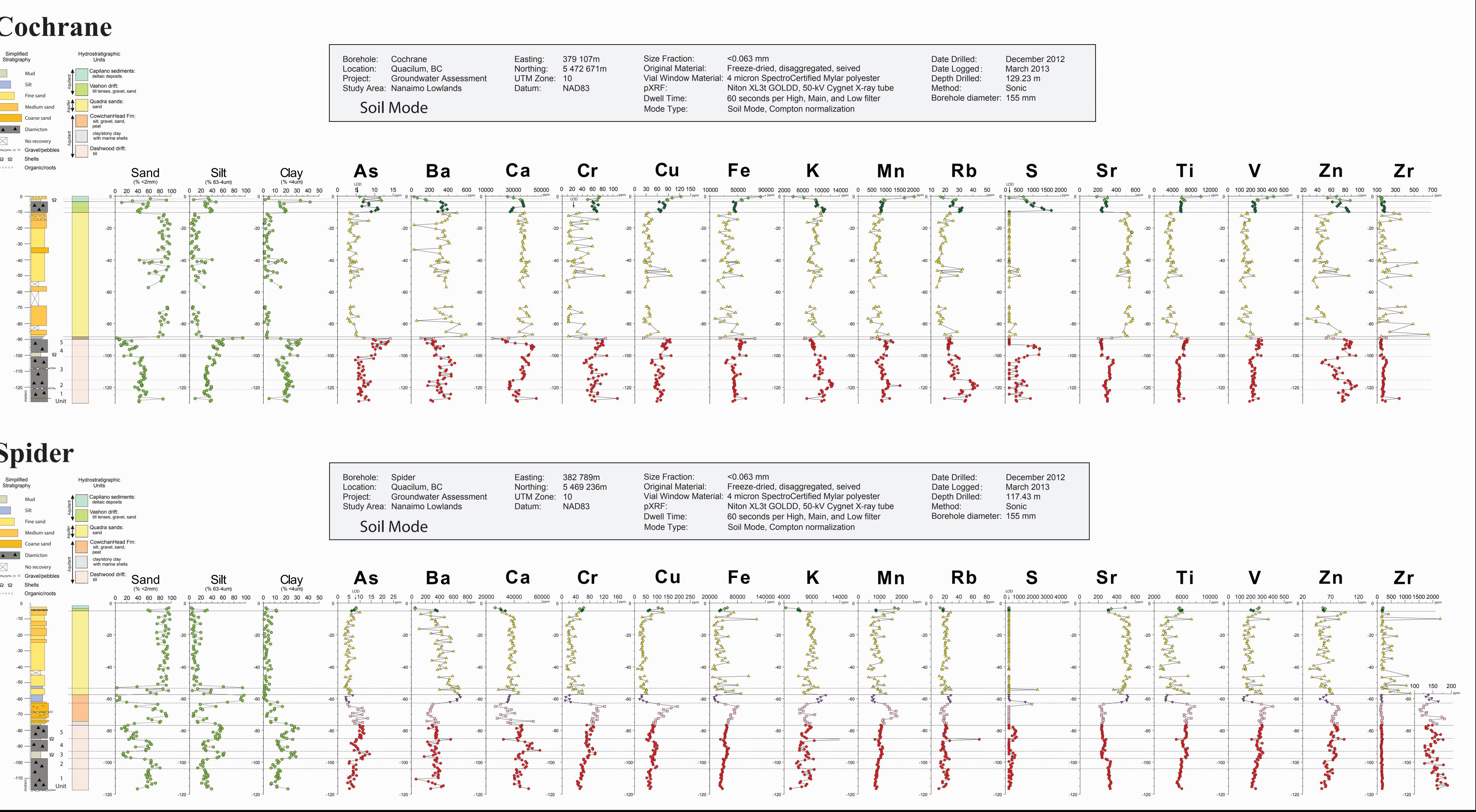


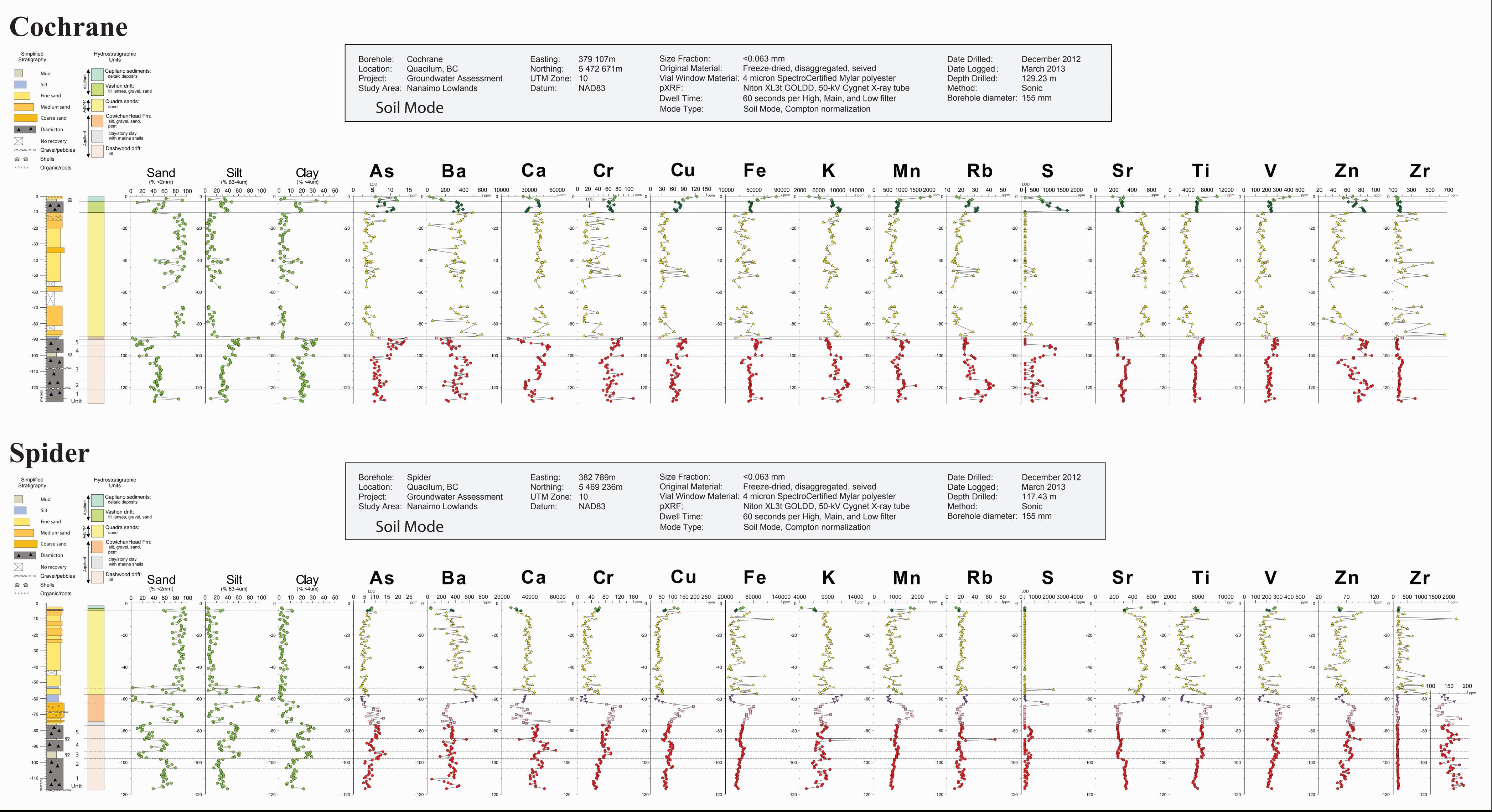
For the Spider borehole Dashwood drift populations display less clumping than Cochrane and occupy an area more towards the +PC 2 zone. These sediments also display a mixture of plutonic lithologies derived from the Coast Mountains and volcanic and sedimentary lithologies from the east coast of Vancouver Island.

For more information, please contact R.D. Knight (ross.knight@canada.ca)

Borehole Chemo-Stratigraphy + Grain Size Data

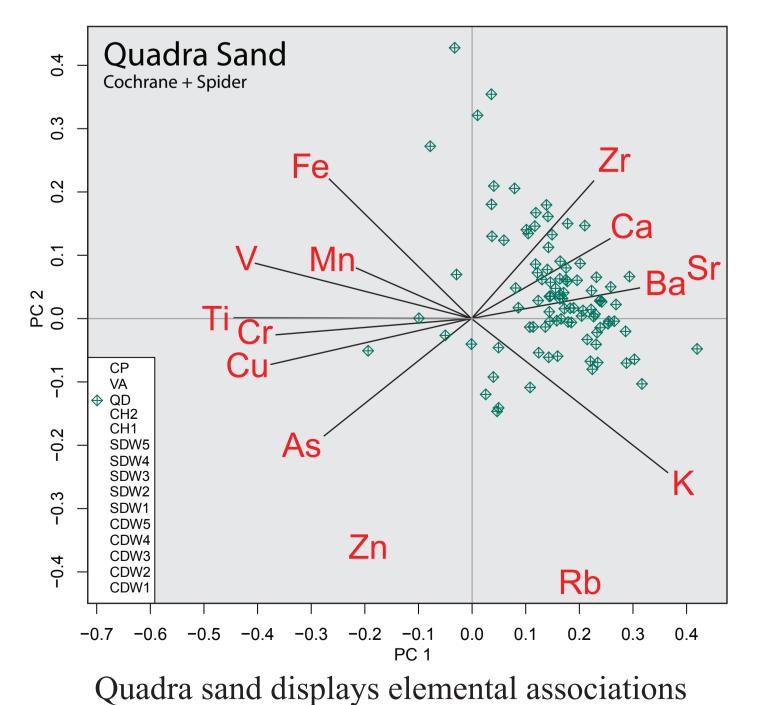
Data obtained by pXRF spectrometry can be plotted and compared with the visual stratigraphic sediment descriptions and laboratory grain size analyses. An upwards increase in silt content of the Dashwood Drift is reflected in an upwards increase in concentration of many elements such as Ca, Cr, Cu, Fe etc as seen in the Spider borehole. The Cowichan Head Fm. is expanded in the Spider borehole where the lower unit is comparable to the Dashwood Drift and the upper unit is comparable to the overlying Quadra sand. The Quadra sand displays decrease in silt and clay content compared to other sediments and displays an increase in Sr, and a decrease in Sr, an in the concentration of elements such as Ba, Fe, and Mn.





Lower Cowichan Head Fm sediment display element similarities with the underlying Daswood Drift diamictons and marine sediments. Upper Cowichan Head Fm. sediments display elemental similarites with the overlying Quadra sand.

Principal Component Analysis: Scores and Loading



related to granitic provenance of the Coast

doi:10.4095/299725

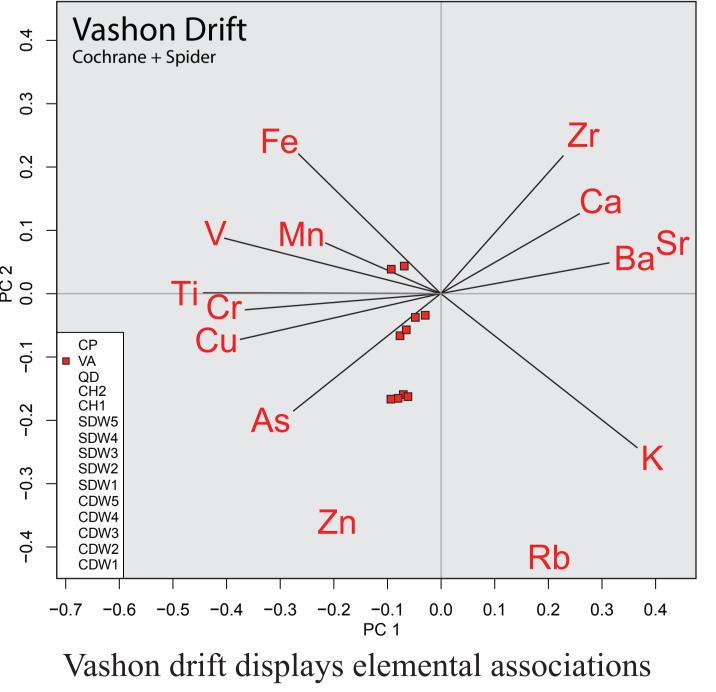
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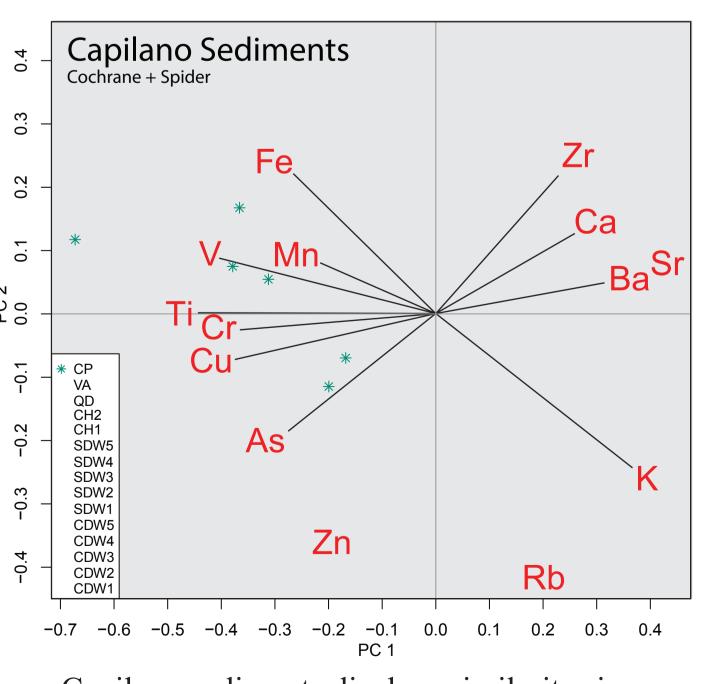
Mountains.



Dashwood drift.



similar to unit two of the Spider and Cochrane



Capilano sediments displays similarites in elemental associations to the lower Cowichan Head Fm.

Date presented: September 2016

Conclusions

To our knowledge these results are the first systematic geochemical characterization of late Pleistocene succession in the Nanaimo Lowlands. The Cochrane and Spider borehole data demonstrates that pXRF geochemistry is valuable in differentiating stratigraphic units and can provide insight into the provenance of these sediments.



Presented at Geological Society of America Annual Meeting and Exposition, Denver 2016