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High-precision Pb-isotopic systematics of the Quesnel Arc:
a potential exploration tool for distinguishing lower versus upper Nicola Group volcanic rocks

Systématique des isotopes du Pb (haute précision) de l'Arc de Quesnel:
un outil d'exploration pour distinguer entre les roches volcaniques inférieures et supérieures du groupe de Nicola.

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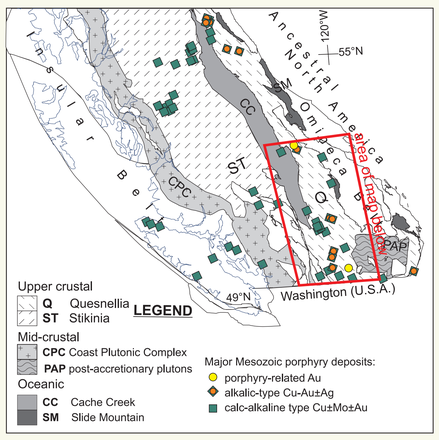
ABSTRACT

The lower Nicola Group (Triassic) rocks in south-central British Columbia are generally considered to have exploration potential for Cu-Au mineralization, but can only rarely be distinguished from the upper (Early Jurassic) uneconomic portions of the stratigraphic package because most exposures are fault-bounded, and the rocks (basalts to trachy-andesites) are not dateable by conventional methods. The current study provides high-precision geochemical and isotopic compositions (Rb-Sr, Sm-Nd, Lu-Hf, and Pb-Pb) of the Quesnel arc, with emphasis on the dated intrusive counterparts to the Nicola Group. Preliminary results indicate a distinct shift in isotopic compositions between the latest Triassic mineralizers (e.g. Copper Mountain, Iron Mask) and the barren Early Jurassic granitoid batholiths (e.g. Pennask, Bromley). This trend is apparent in all 4 isotopic systems, but is best revealed in the $^{207}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ systematics of samples from this arc assemblage, in which the mineralized intrusions form one linear trend, while the younger, barren intrusions form another linear trend, with higher $^{207}Pb/^{204}Pb$. Importantly, samples of undifferentiated Nicola Group volcanic rocks plot on one trend or the other, and therefore may be separable with respect to mineralization potential on the basis of their Pb-isotopic compositions.

The identification of these trends in the Pb-isotopic system is made possible by the very high precision of the analyses by multi-collector inductively coupled plasma mass-spectrometry (MC-ICP-MS) compared to earlier Pb-isotopic studies of similar rocks, which were determined by a thermal ionization mass spectrometry (TIMS). The analytical uncertainty by MC-ICP-MS is >10x smaller than that by TIMS, and thus data which formerly plotted as scattered fields now resolve into tightly linear trends. The analytical uncertainty of $^{207}Pb/^{204}Pb$ measurements by TIMS exceeds the compositional range between the two trends identified in this study, and therefore this important compositional relationship between suites was formerly obscured. Analysis of additional samples for Pb-isotopic compositions will be undertaken to confirm whether the trend revealed by the new MC-ICP-MS results is reliable for use as an exploration tool at a regional scale, and to test whether older lithologies conform to the trend thus far observed (earliest Late Triassic intrusions, e.g. Guichon Batholith).

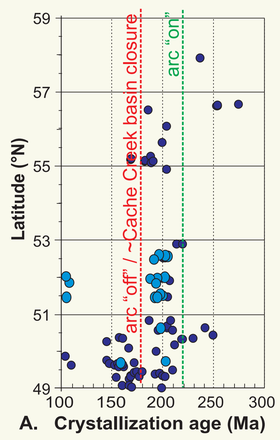
BACKGROUND

MESOZOIC igneous rocks of the **QUESNEL TERRANE** host numerous alkaline Cu-Au and calc-alkaline Cu **PORPHYRY DEPOSITS.**



Deposit information from MINFILE (2006) and CordMinAge 2006 (Madsen *et al.*, 2006).

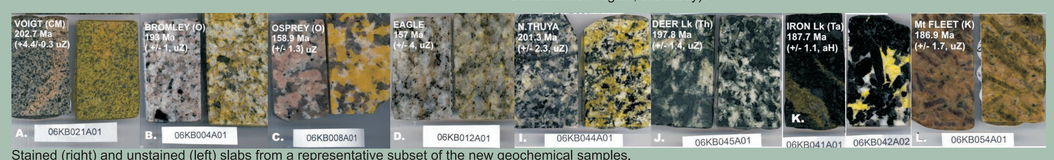
The **HOST ROCKS** consist of a **LATE TRIASSIC** to **EARLY** (ca. 220-180) **ARC** assemblage .



A plot of latitude vs. U-Pb crystallization age for Quesnel terrane igneous rocks indicates arc-wide (along-strike) magmatic activity occurred between 220-180 Ma. Prior and subsequent magmatism is local in nature.

New geochemical samples for this study are inclusive of the entire interval of arc magmatism.

Source: dark blue = BCAge 2004 (Breitsprecher & Mortensen, 2004), query criteria = A-rated, U-Pb, crystallization. Light blue = preliminary U-Pb ages, studies in progress (R. Friedman & P. Schiarizza: Takomkane & Thuya regions; B. Davis & K. Breitsprecher: Simalkameen region, this study).

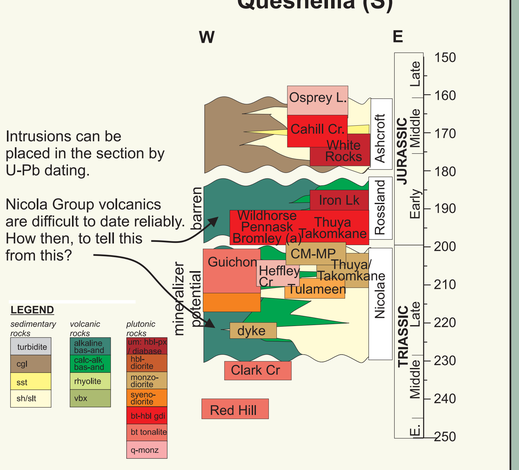


Stained (right) and unstained (left) slabs from a representative subset of the new geochemical samples.

PROBLEM

ECONOMICALLY VIABLE DEPOSITS are typically hosted in the **OLDER, TRIASSIC** intrusive to sub-volcanic phases of the arc assemblage. The **CORRELATIVE EXTRUSIVE** phases of the Nicola Group are generally considered to have **EXPLORATION POTENTIAL.**

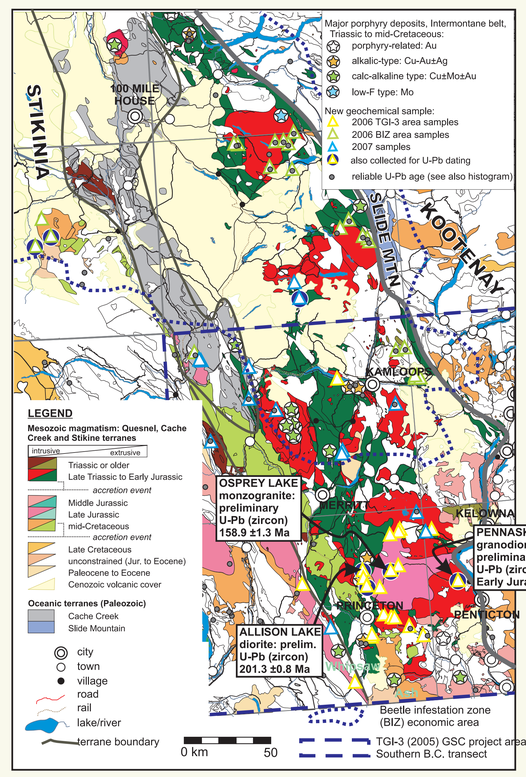
Distinguishing lower Nicola Group rocks from the upper (barren) portions of the stratigraphy is difficult in the field or by other means, due to the poor stratigraphic constraint across numerous fault-bounded sequences (e.g. Mortimer, 1987; Smith et al., 1995).



Intrusions can be placed in the section by U-Pb dating.

Nicola Group volcanics are difficult to date reliably. How then, to tell this from this?

Exploration of the lower Nicola Group rocks would benefit from the **DEVELOPMENT OF A SYSTEMATIC, RELIABLE TOOL** by which to **IDENTIFY THE ROCKS OF INTEREST** (Lower Nicola Group).



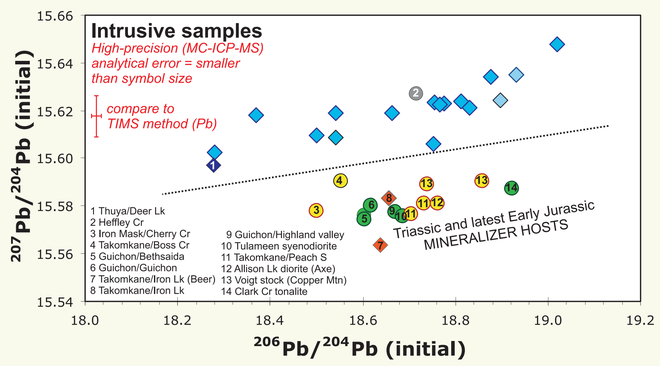
Mesozoic geology and related porphyry deposits of the southern Quesnel terrane, British Columbia. Sample localities for the new geochemistry (triangles) and U-Pb geochronology (triangle in circle) are also shown. Geology from Massey *et al.*, (2005). Preliminary U-Pb ages by Bill Davis (GSC, Ottawa).

RESULTS

We present NEW HIGH-PRECISION (MC-ICP-MS) Pb-isotopic compositions of the Quesnel intrusives.

The samples form two trends:

the younger, (Jurassic) barren rocks are more radiogenic (more ^{207}Pb at a given ^{206}Pb) than the older (Triassic), predominantly mineralized units.



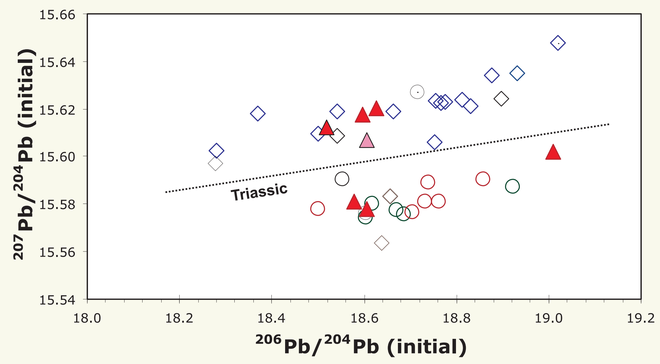
Samples from U-Pb dated intrusions of the Quesnel arc form two trends in $^{207}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ space.

Trends are observed with respect to both age and mineralization.

IN GENERAL, the younger (198-190 Ma), barren granodioritic to quartz monzonitic phases of the arc are more radiogenic than older (220-200 Ma), mineralized phases.

EXCEPTIONS:
The trend is not purely temporal:
- by Pleinsbachian time (ca. 190-188 Ma), Pb-isotopic composition indicates a return to a less radiogenic (this study), but Cu-rich (e.g. Schiarizza & Boulton, 2006) source for the magma.

The trend is not purely economic:
- Early Jurassic Deer Lake stock plots with the more radiogenic samples of its age, but has Cu-potential (e.g. Schiarizza & Israel, 2001).

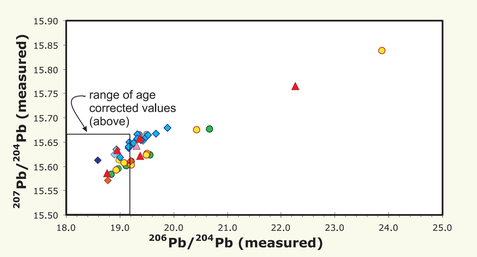


A SMALL SAMPLING OF UNDIFFERENTIATED VOLCANIC ROCKS OF THE NICOLA GROUP PLOT CLEARLY ON ONE TREND OR THE OTHER.

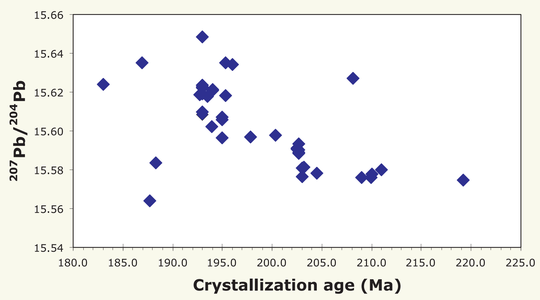
A single sample with known stratigraphic position in the upper (Early Jurassic) part of the section (Beatty et al., 2006) plots on trend with its Early Jurassic intrusive counterparts.

The Pb-isotopic systematics of the Quesnel arc is apparently applicable as an exploration tool, to separate lower from upper Nicola Group volcanic rocks.

The method should be tested against a larger sample set of Nicola Group volcanic rocks.



The trends are already observable from the measured $^{207}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ values (above), and are preserved after the correction to emplacement age (top). Note change of scale vs. age-corrected values.

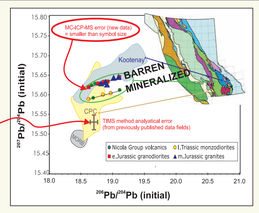


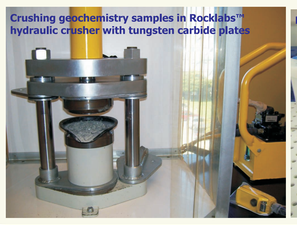
General time-progressive trend towards increasingly radiogenic Pb-isotopic compositions, intrusive (U-Pb dated) samples.

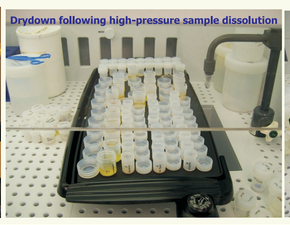
ANALYTICALLY SPEAKING: What permits the identification of this trend?

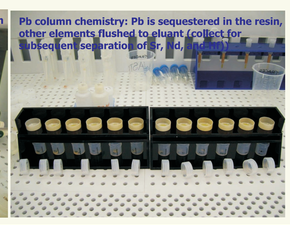
HIGH-PRECISION (MC-ICP-MS) Pb-isotopic analyses, as its name implies, permits identification of linear trends because of very small analytical error associated with the instrument (<100ppm, or better than 0.01% error). Such trends are not resolvable by the commonly used TIMS method, for which larger (>10-100X) analytical error produces scatter in $^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ space.

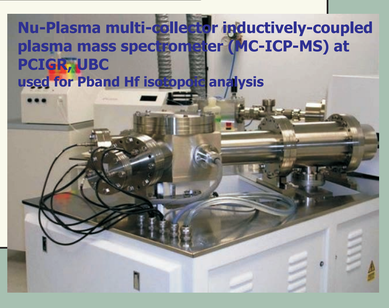
Previously reported Pb-isotopic compositions (TIMS) for southern Cordilleran arc rocks has ^{207}Pb error which exceeds the resolution between the trends defined by the new MC-ICP-MS analyses.











CONCLUSIONS

1. ***Intrusive rocks from the Quesnel arc are separable into broad linear trends on the basis of $^{207}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$:*** Triassic hosts to Cu or Cu-Au despoits are less radiogenic than barren Early Jurassic granitoids.

2. ***The relative position of the undatable volcanic rocks to the overall stratigraphy can be inferred from their Pb-isotopic compositions relative to the trends established by the U-Pb dated intrusive rocks.*** Nicola Group volcanic rocks of unknown stratigraphic position plot on either one trend or the other. A test sample with known "upper" stratigraphic position (*fossil evidence, Beatty et al., 2006)* plots as expected on the "Jurassic barren" trend.

3. ***The trends are discernable only if Pb is analyzed at high-precision using a MC-ICP-MS instrument;*** analytical error of the TIMS method exceeds, and thus obscures, the offset in $^{207}Pb/^{204}Pb$ space between the two trends.

REFERENCES

Beatty, T.W., Orchard, M.J., Mustard, P.S., 2006: GAC Special Paper 45: 483-504. **Breitsprecher, K., Mortensen, J.K. (compilers), 2004:** BC MEMPR Open File 2004-3, 7763 records, 9.1 Mb. **Breitsprecher, K., Scoates, J.S., Anderson, R.G., Weis, D. 2007:** Geological Fieldwork 2006, BC MEMPR Paper 2007-1: 247-258. **Madsen, J.K., Breitsprecher, K. Anderson R.G., (compilers) 2006**: GSC Open File 4969, Release 1.1, 1.9 Mb. **Massey, N.W.D., MacIntyre, D.G., Desjardins, P.J., Cooney, R.T. 2005:** BC MEMPR Geoscience Map 2005- 3, scale 1:1 000 000. **MINFILE 2006:** BC MEMPR URL <http://www.em.gov.bc.ca/Mining/Geolsurv/Minfile/> [Nov 2006]. **Mortimer, N. 1987:** CJES 24: 2521-2536. **Schiarizza, P., Boulton, A. 2006:** Geological Fieldwork 2005, BC MEMPR Paper 2006-1: 163–184. **Schiarizza, P., Isreal, S. 2001:** Geological Fieldwork 2000, BC MEMPR Paper 2001-1: 1-30. **Smith, A.D., Brandon, A.D. St. John Lambert, R. 1995:** CJES 32: 437-446.

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