

**D'où vient l'or des gisements orogéniques -
magmatique ou métamorphique ? Réponse à partir des
volatiles en inclusions fluides et des cartographies de
pyrites au LA-ICP-MS; exemples de la Nouvelle-
Zélande, du Burkina Faso et du Canada.**

Damien Gaboury, PhD, Géo
Professeur



UQAC
Université du Québec
à Chicoutimi

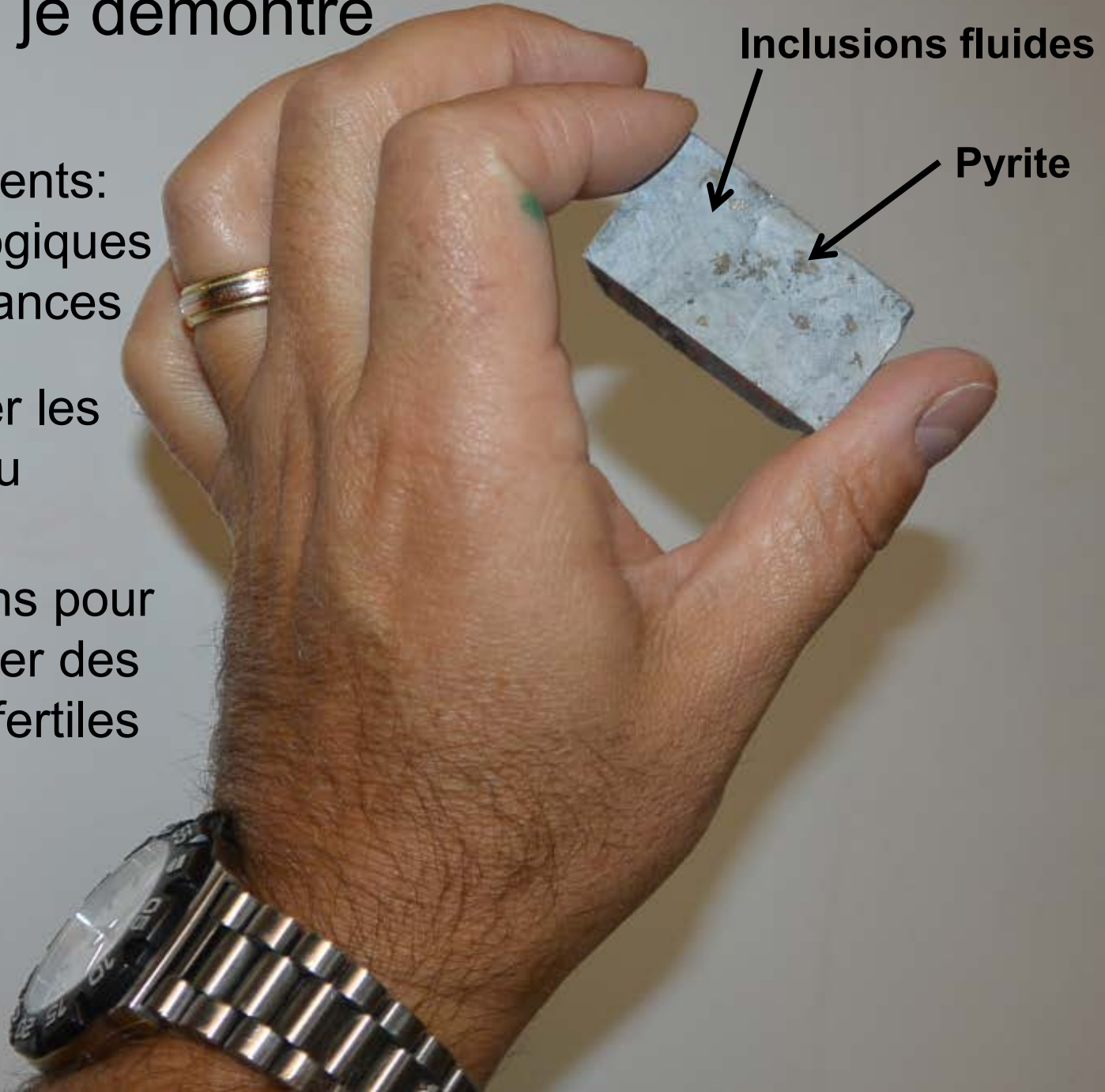
Ce que je démontre

Developments:

- Technologiques
- Connaissances

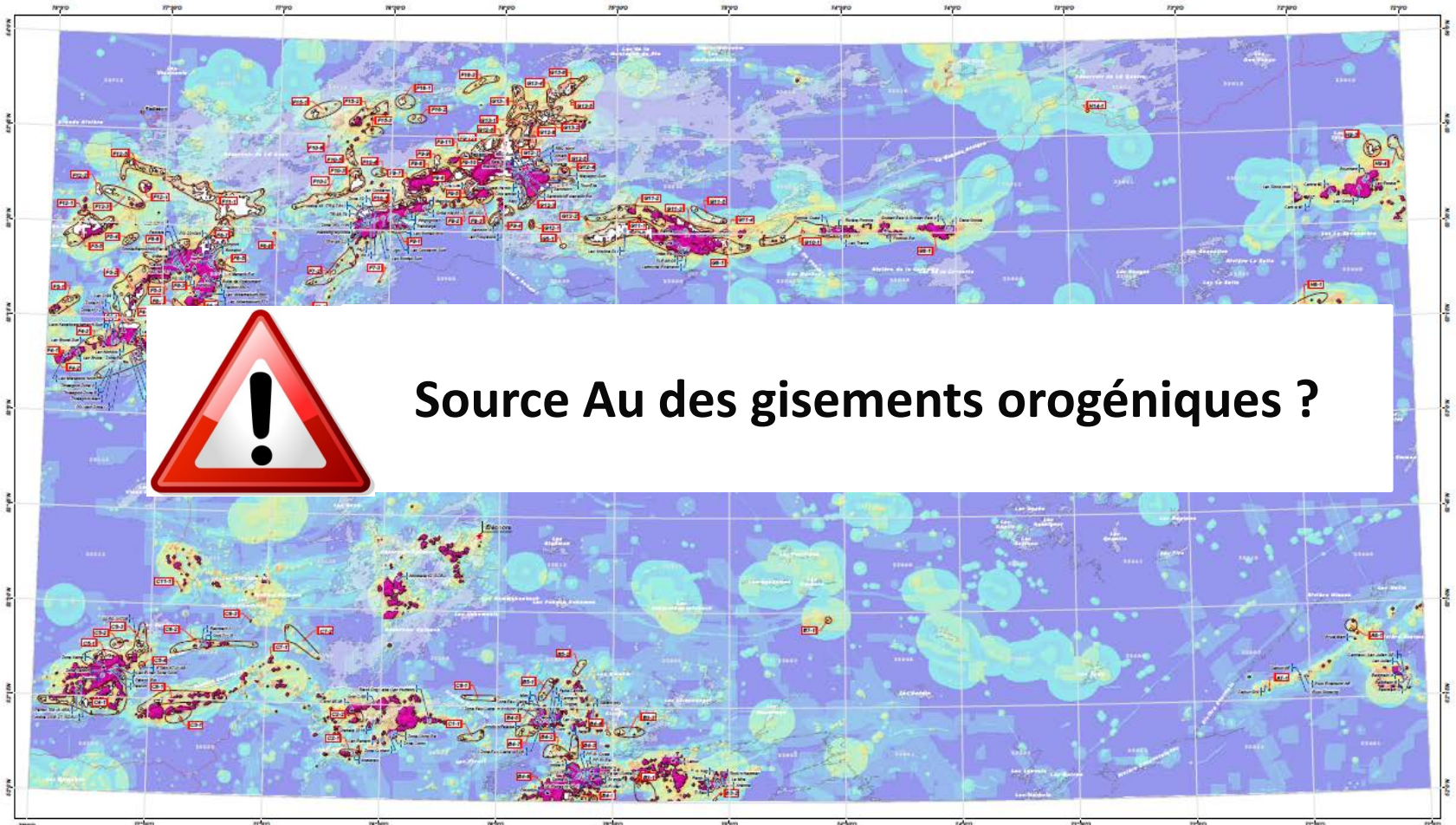
Déterminer les sources Au

Implications pour sélectionner des ceintures fertiles

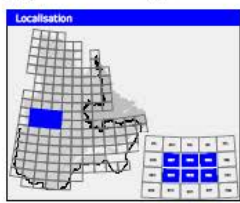


Où chercher pour trouver des gisements d'or ?

Carte d'évaluation du potentiel aurifère de type or orogénique de la Baie-James



Source Au des gisements orogéniques ?



- Gîtes aurifères**
- ✕ Mine fermée
 - ⊗ Gisement avec tonnage avéré
 - ⊙ Gîte travaillé
 - ▲ Indice, aucun travail
 - CQ-1 Numéro de cible
 - Cible : Zone (ou portion de zone) de haute favorabilité (Date de réajustement en date du 06 février 2003)
 - Zone de haute favorabilité
 - Municipalité

Cette carte est extraite du RP 2009-01 dont le résumé est disponible en 2009. Production du potentiel en or orogénique de type or orogénique de la Baie-James, Ministère des Ressources naturelles et de la Faune, RP 2009-01, 1:500 000.

Cette évaluation du potentiel en or orogénique de type or orogénique de la Baie-James a été réalisée par l'équipe de cartographie géologique de la Baie-James (GCGP) du MRNF. Les autres données et informations géologiques ou courtes de référence sont accessibles dans le document RP 01 2009-01, Les données de référence pour la Baie-James à l'échelle 1:500 000, ainsi que à l'adresse Au-1:500 000 et 01:500 000 sont aussi disponibles sur le web.

Production: Ministère des Ressources naturelles et de la Faune, Québec Québec.

Évaluation: Daniel Lavoie (Géologie Québec)

Collaborateur: Marc Beaudin

Rédaction technique: Hélène Lefebvre

Cartographie: Direction de l'information géographique, Québec Québec

www.mrnrf.gouv.qc.ca

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Métadonnées

Résumé de référence géologique : 000000 000 000

Échelle de référence géologique : 1:500 000

Projection cartographique : Mercator Transverse Universelle (MTU), Azimut 90

Source

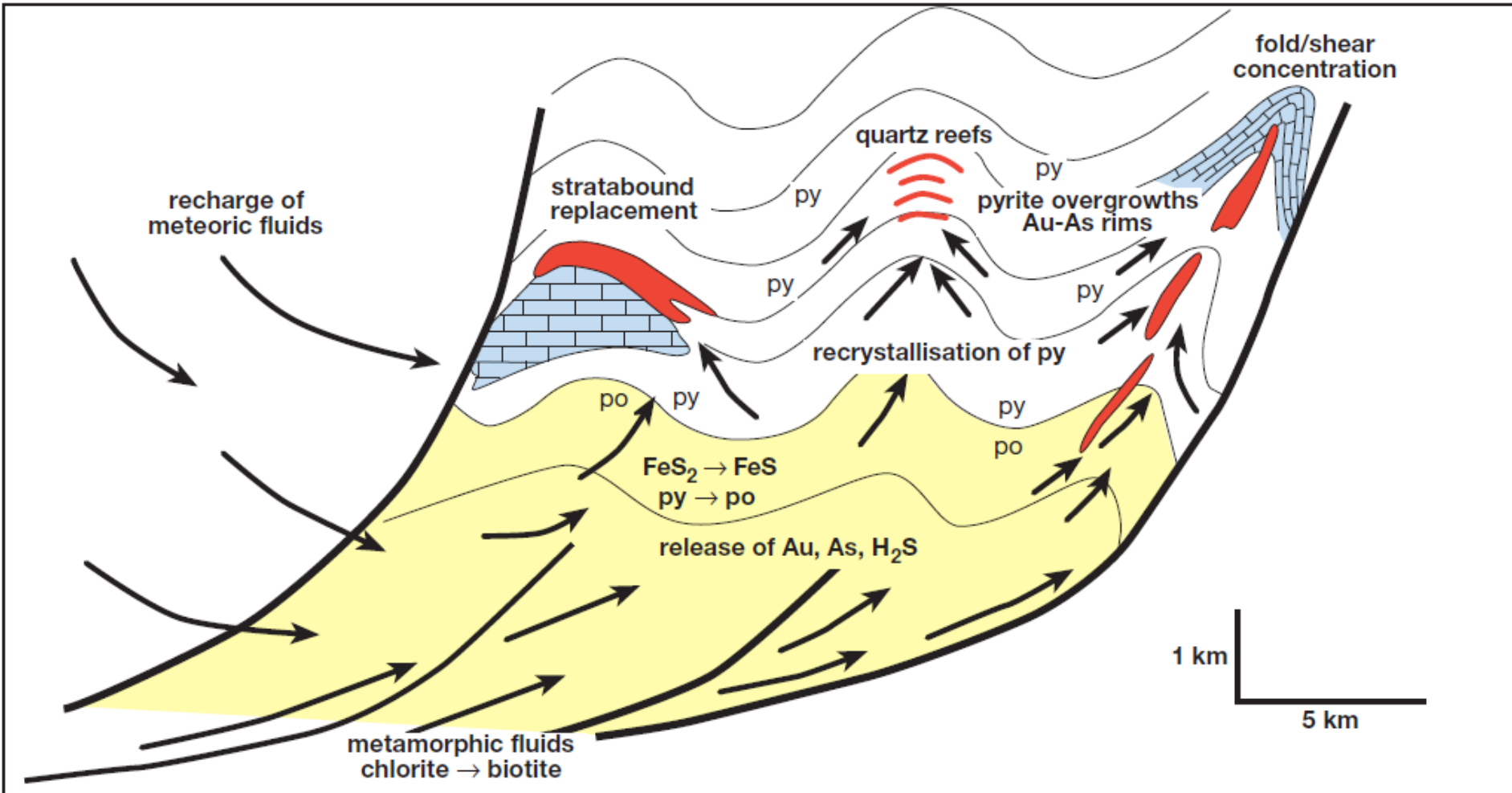
Topographie : Ministère des Ressources naturelles du Canada

1 0 10 20 30 40 km

1:500 000

EP 2008-01 C001

Modèle métamorphique: Au, As, S: Relâchés des sédiments riches en MO lors de la conversion Py-Po



Approche conceptuelle

Gisement

Au^0



H_2O, CO_2



Volatiles
discriminants ?

Schistes
verts

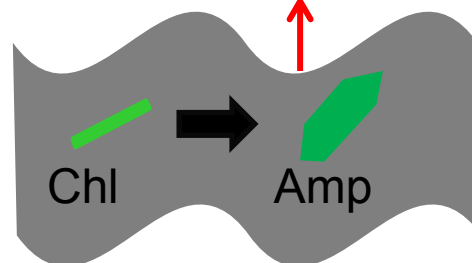
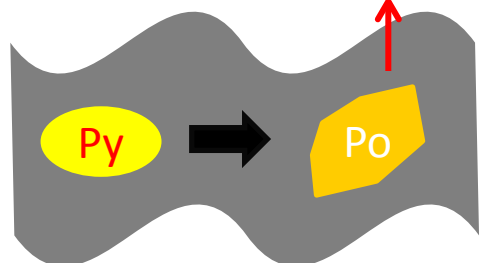
$H_2O + CO_2 + AuHS_2^-$

Amphibolite

Au, Ag, As, Sb

H_2O, CO_2

MO: CH_4, N_2, C_2H_6



Shale

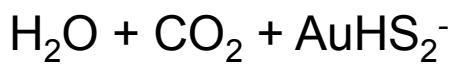
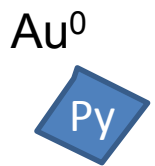
Bases scientifiques

Gaboury (2013)

Large et al. (2007, 2009, 2011, 2012)

C₂H₆ : Traceur ultime

Gisement



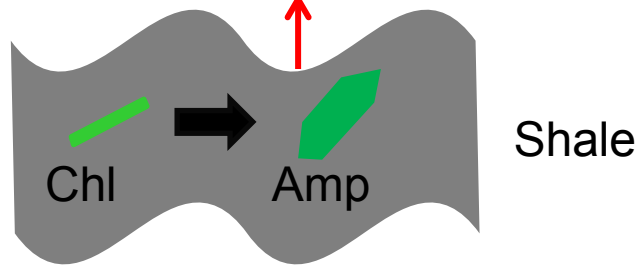
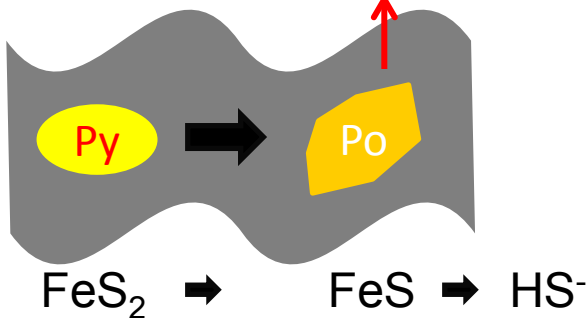
Schistes verts

Pitcairn et al. (2010)
Thomas et al. (2011)

Amphibolite

Au, Ag, As, Sb

H₂O, CO₂ MO: CH₄, N₂, C₂H₆



Tomkins (2010)

Article « in press » dans *Geology*

Démonstration de la signification du C_2H_6

Does gold in orogenic deposits come from pyrite in deeply buried carbon-rich sediments?: Insight from volatiles in fluid inclusions

Damien Gaboury

Laboratoire de Métallogénie Expérimentale et Quantitative (LAMEQ), Université du Québec à Chicoutimi (UQAC), 555 Boulevard de l'Université, Chicoutimi, Quebec G7H 2B1, Canada

ABSTRACT

The origin of volatiles in fluid inclusions was reviewed for testing the involvement at depth of carbonaceous-pyritic sedimentary rocks as the source for orogenic gold mineralization. Fluid inclusions from selected deposits were analyzed by solid-probe mass spectrometry. Fluids are mostly aqueous-carbonic, with variable amounts of N_2 , CH_4 , C_2H_6 , Ar, H_2S , H_2 and He. For fluids with CH_4 and C_2H_6 , their ratios (C1/C2) range from 2.6 to 25.5, indicating that C_2H_6 is sourced from thermally degraded organic matter. Proportions of CO_2 , CH_4 , C_2H_6 and H_2 are highly variable and can be explained by hydrothermal reactions where C_2H_6 is degraded to CO_2 by water consumption. Such reactions may account for the problematic CO_2 -rich, H_2O -poor fluids associated with some of the richest gold districts. Conditions needed for C_2H_6 degradation are also fundamental for forming gold deposits, such as HS-enriched fluids for carrying gold and local weakly oxidizing conditions for promoting gold precipitation. The C_2H_6 content is recorded in fluids from Mesoarchean to Cretaceous gold deposits, providing support for a general model where fluids and gold were sourced from deeply buried, carbon-rich, and pyrite-gold-bearing sedimentary rocks.

INTRODUCTION

Recent advances in studies of orogenic gold deposits suggest that the gold is derived from

are generated at the amphibolite transition and moved upward to the gold site; (2) volatiles are not sourced from proximal rocks; (3) fluid inclu-

belt hosts different mineralization styles ranging from quartz-carbonate veins to silicified and sulfurized rocks. The deposits, scattered within an ~ 100 km² area, are hosted in various rock types, including deformed sedimentary and volcanoclastic rocks with mafic sills and lava flows, as well as intrusive rocks, metamorphosed to greenschist facies (Table DR1). Graphitic and pyritic shale horizons occur in the district.

METHODOLOGY

Most samples were subjected to fluid inclusion petrographic examination. All samples are gold-bearing (0.1–286 g/t). Fluid inclusions were analyzed in pure quartz samples by solid-probe mass spectrometry following the method of Gaboury et al. (2008), except for the following parameters. Using a Stanford Research Systems residual gas analyzer (RGA100) with

Systeme analytique du LAMEQ

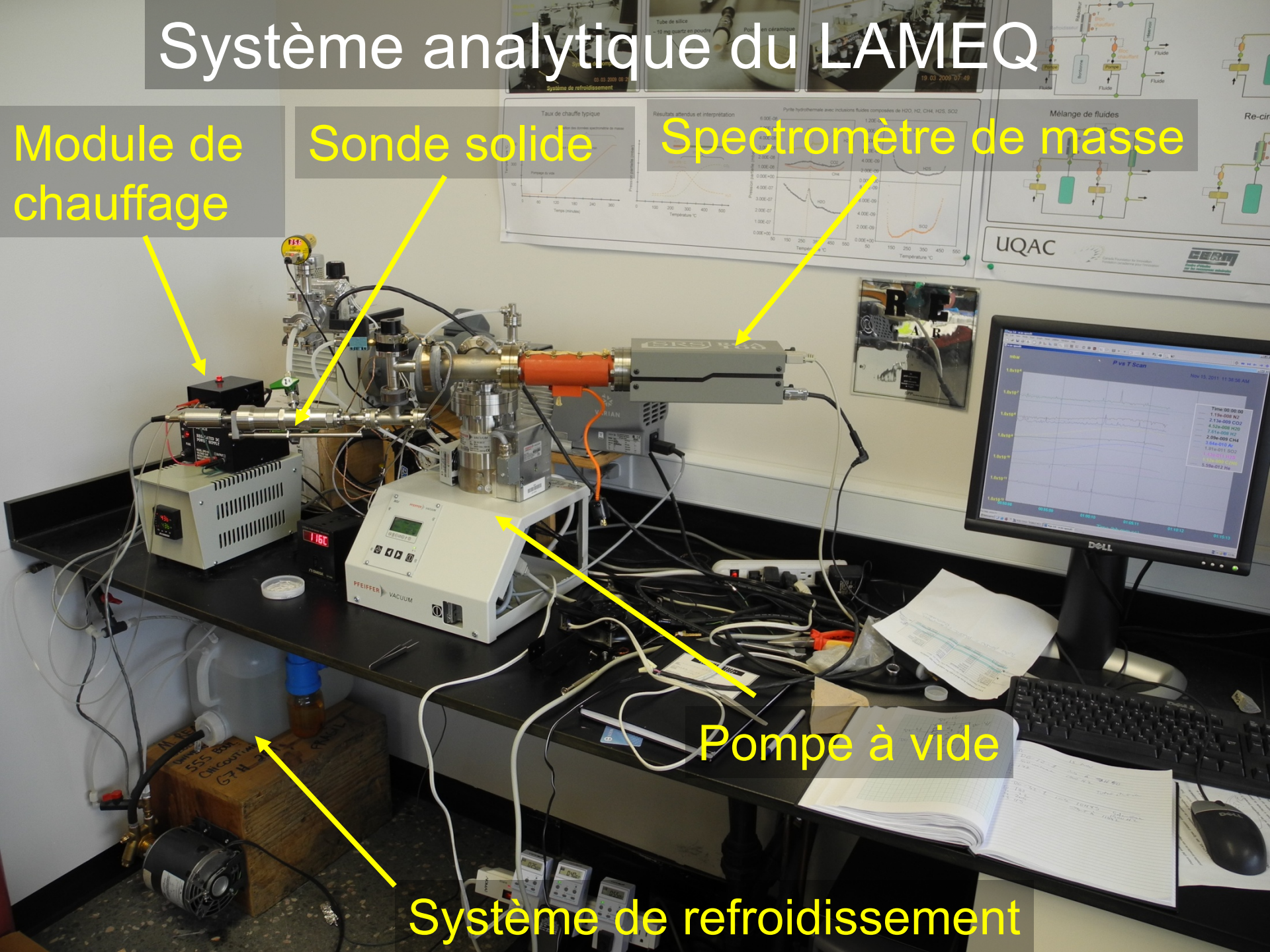
Module de chauffage

Sonde solide

Spectrometre de masse

Pompe à vide

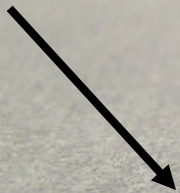
Systeme de refroidissement



Pointe chauffante porte échantillon

Tube de silice

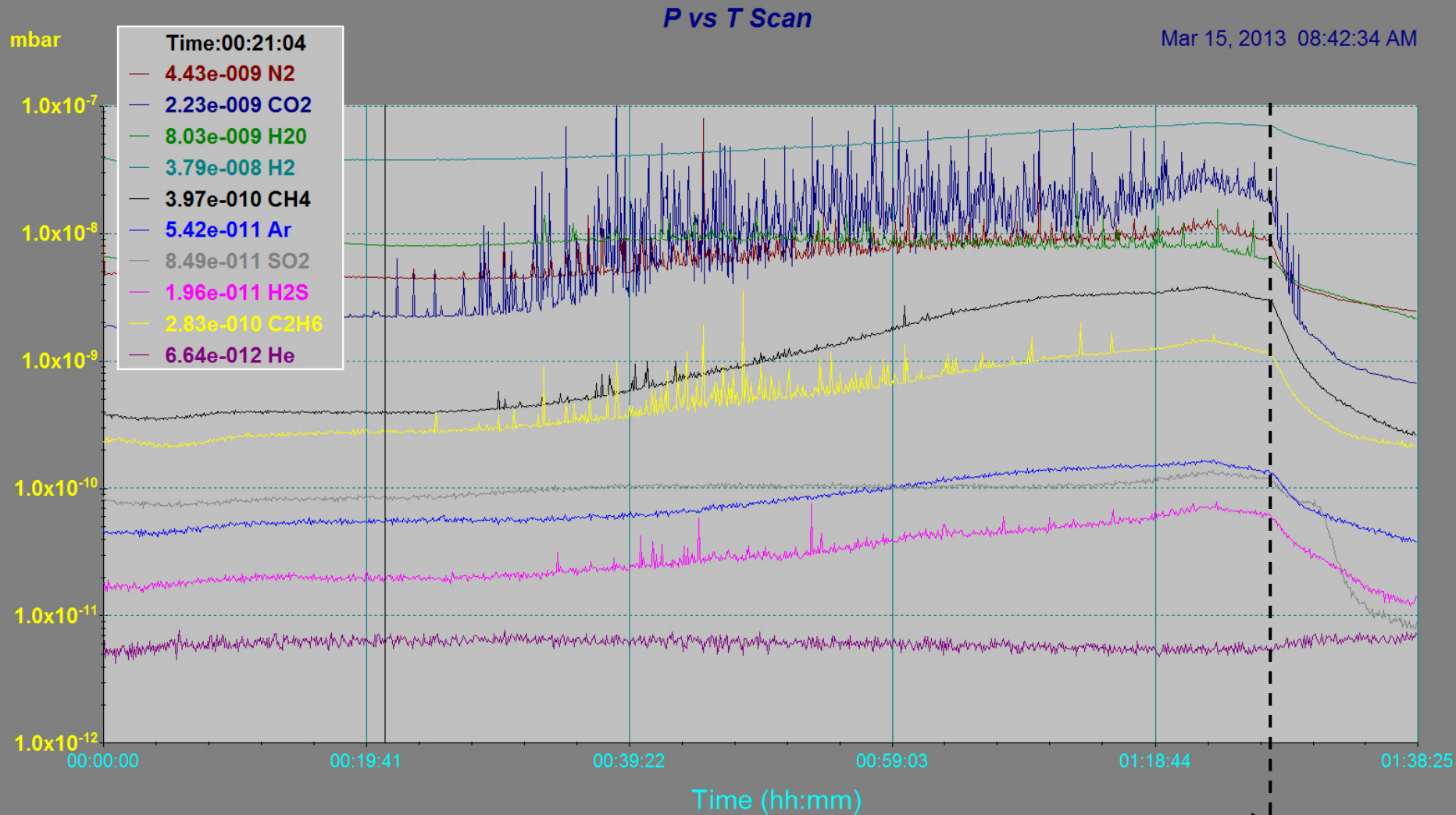
~ 10 mg quartz en poudre



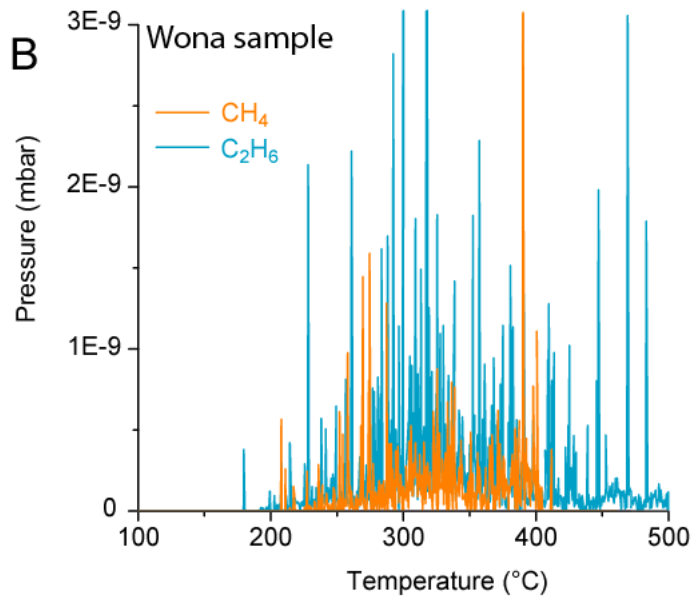
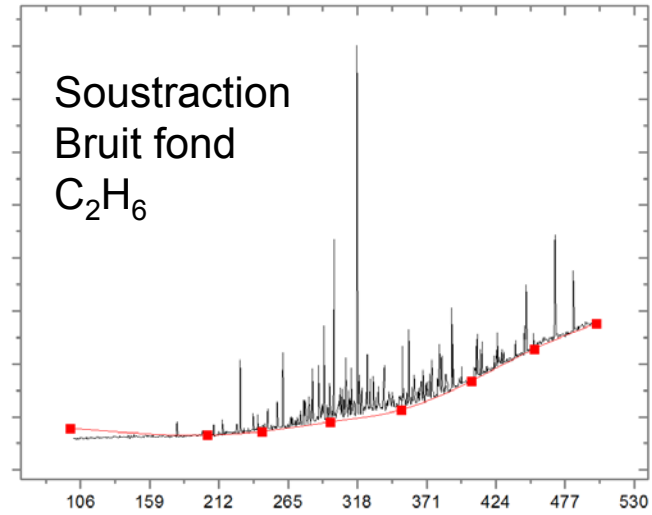
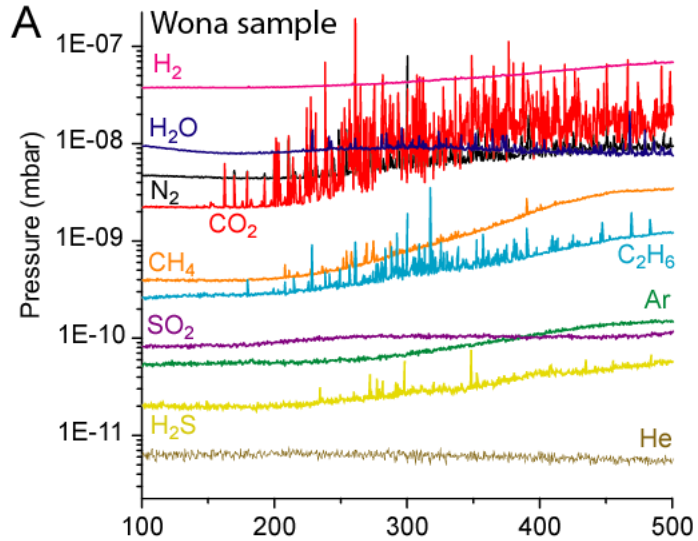
Pointe en céramique



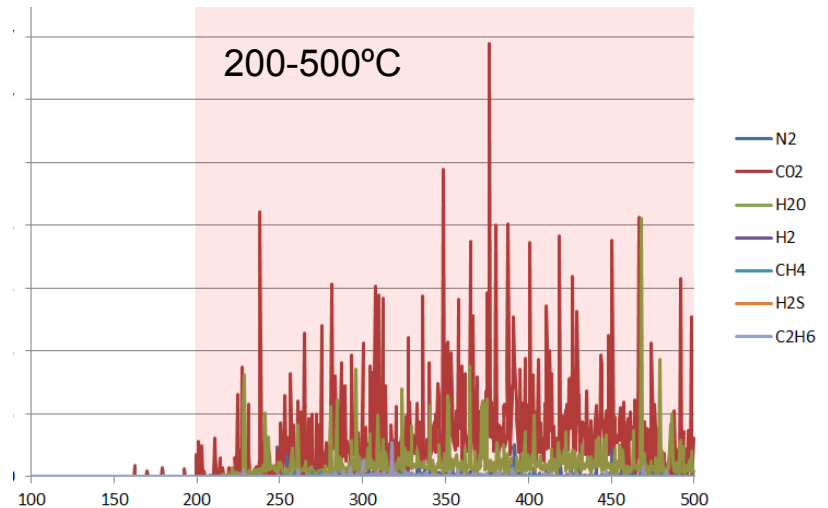
Exemple de données brutes: Wona



Traitement



Calcul des proportions volatiles



Localisation des champs aurifères orogéniques



Canada

Burkina Faso

Nouvelle-Zélande

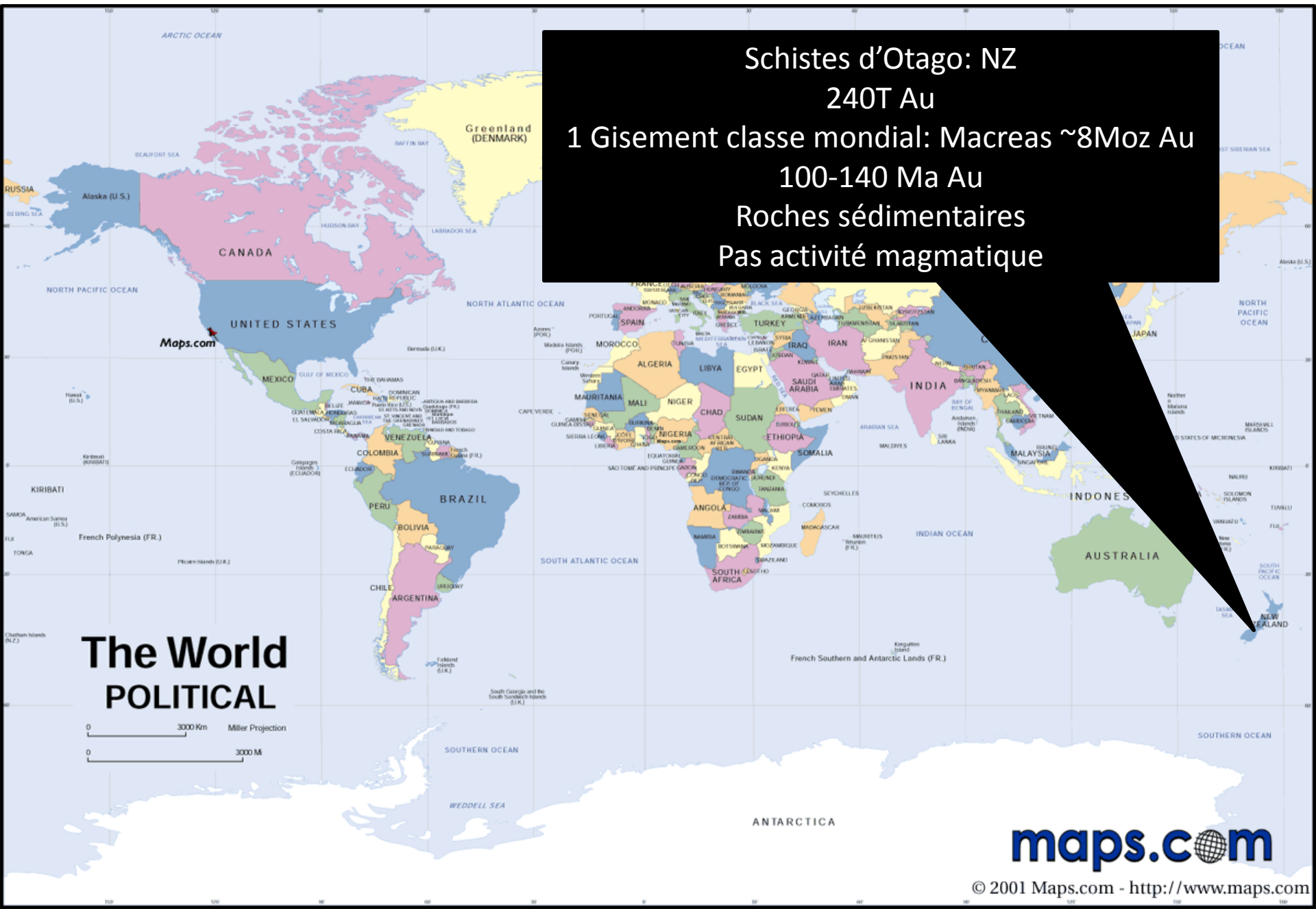
The World
POLITICAL

0 3000 Km
0 3000 M

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Localisation des champs aurifères orogéniques



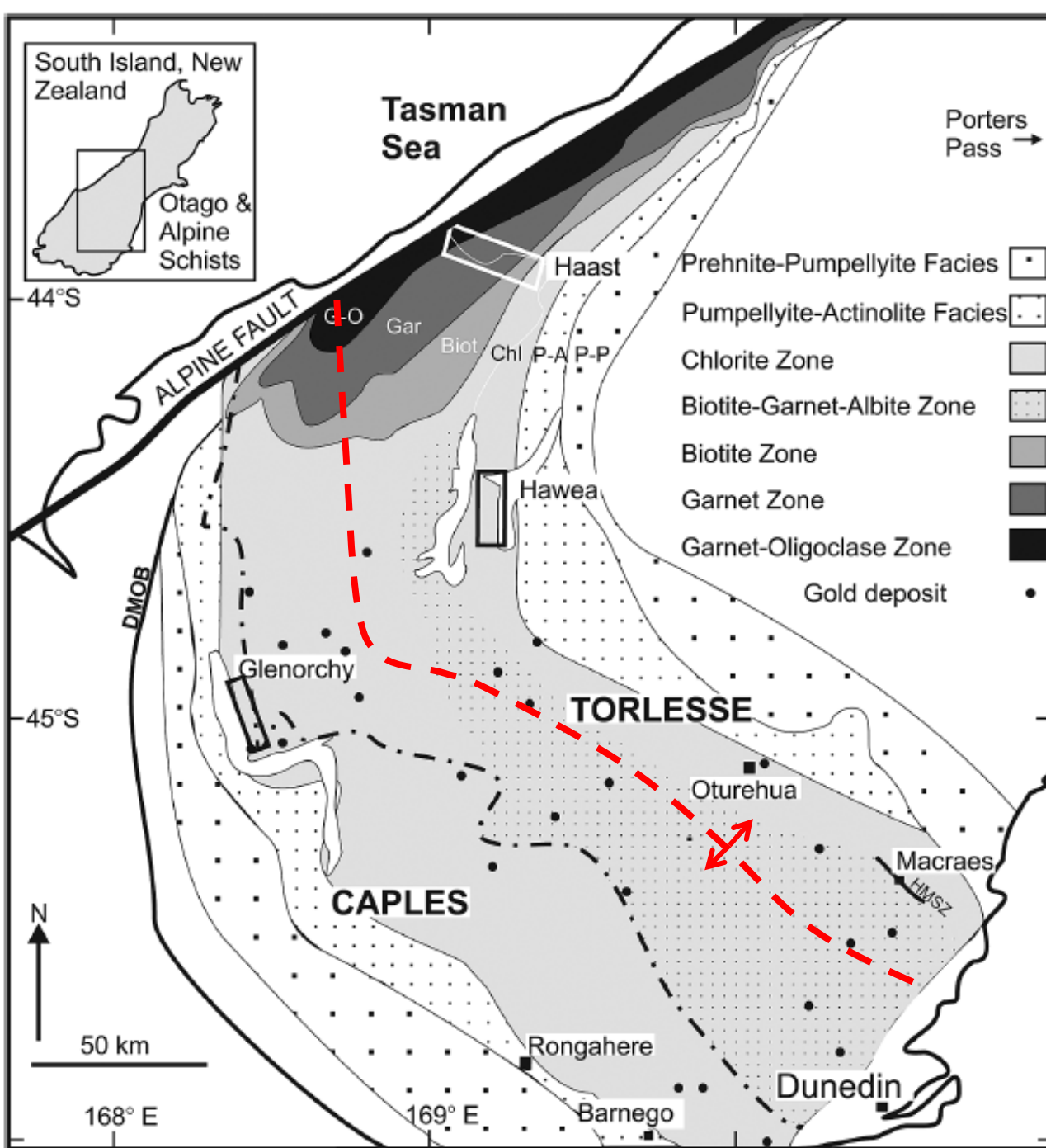
Schistes d'Otago: NZ
240T Au
1 Gisement classe mondiale: Macreas ~8Moz Au
100-140 Ma Au
Roches sédimentaires
Pas activité magmatique

The World
POLITICAL

0 3000 Km
0 3000 M
Miller Projection

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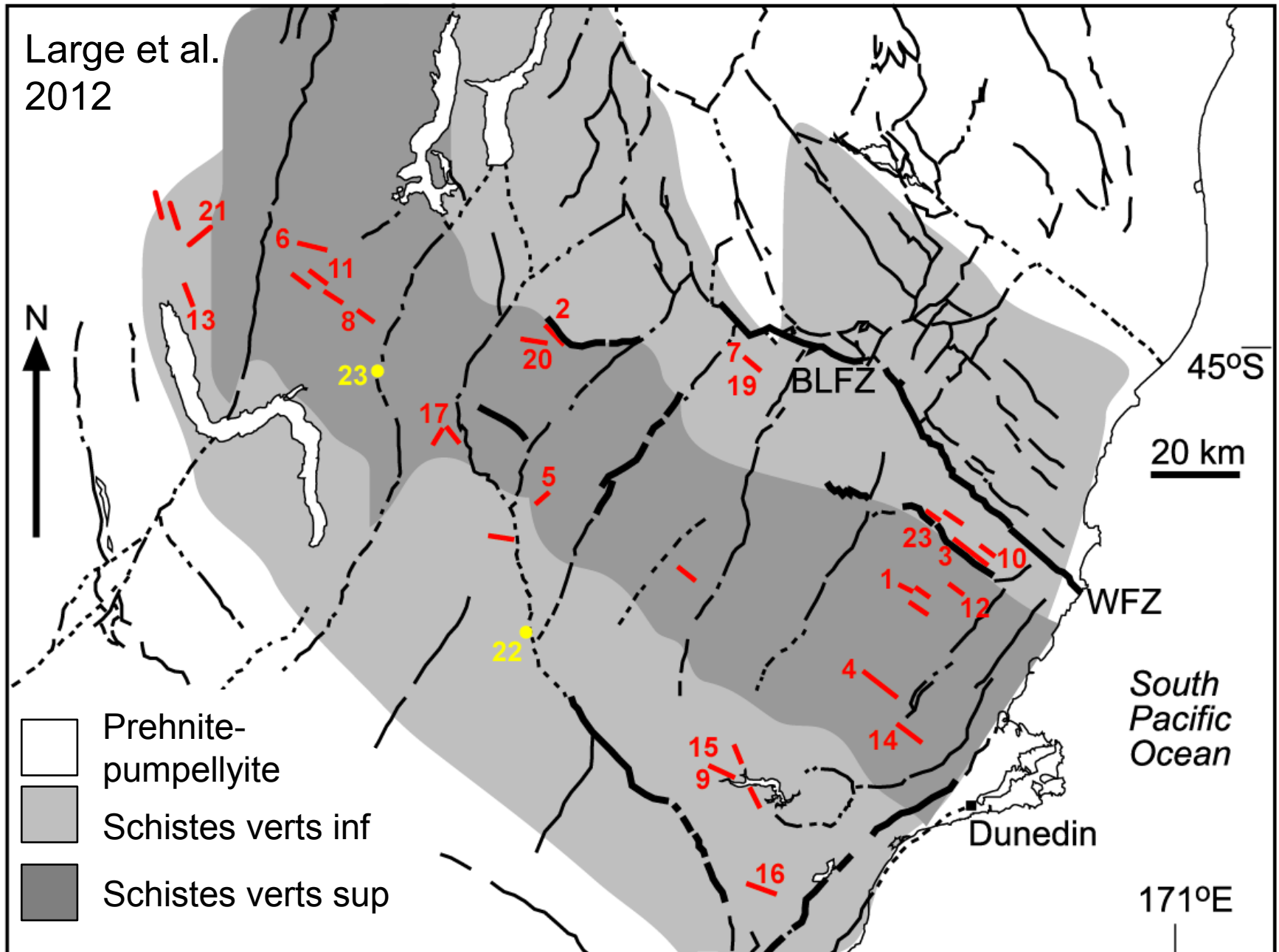


Anticlinal expose au
coeur des facies
métamorphiques plus
élevés

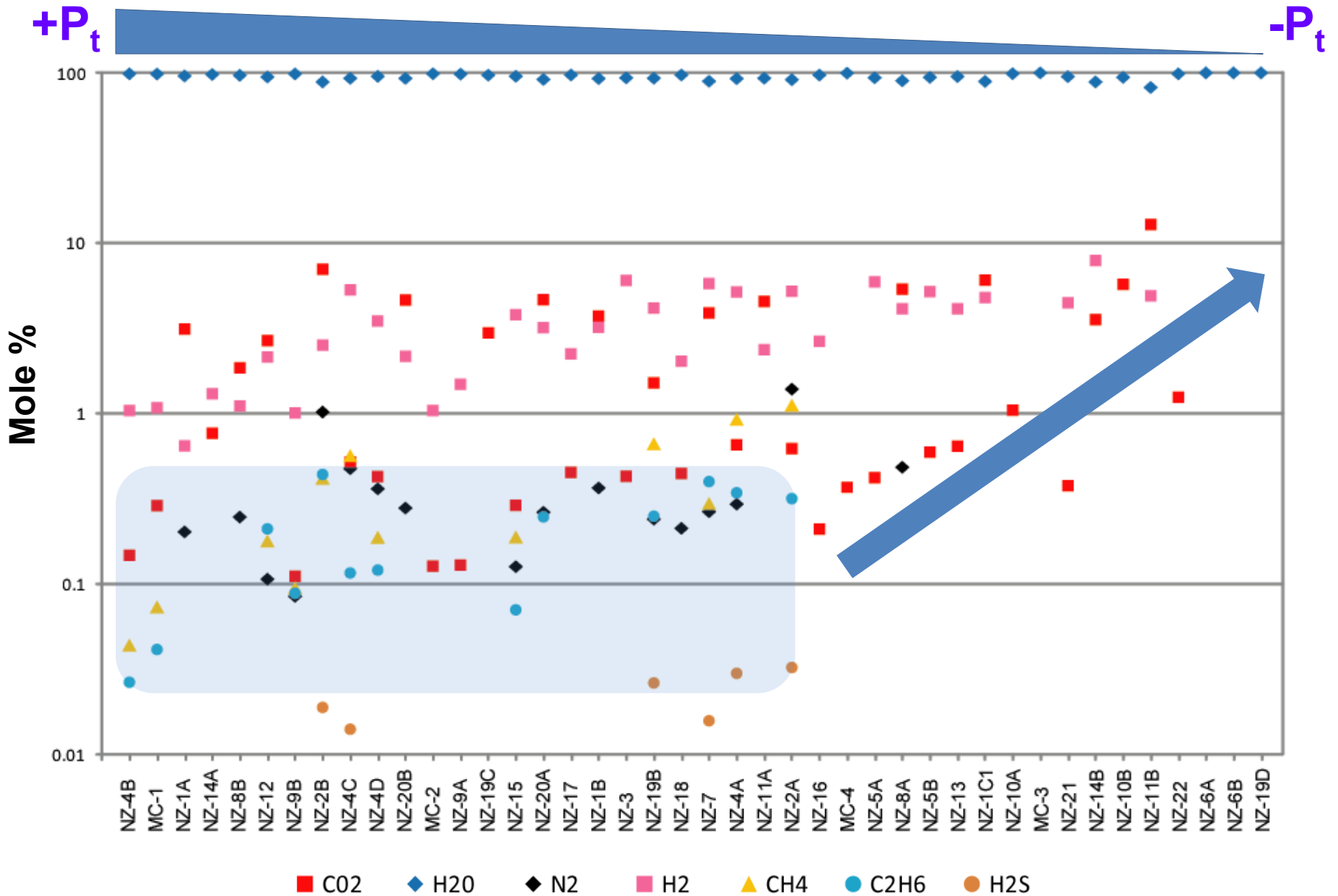
Schistes d'Otago:
Arrow Town



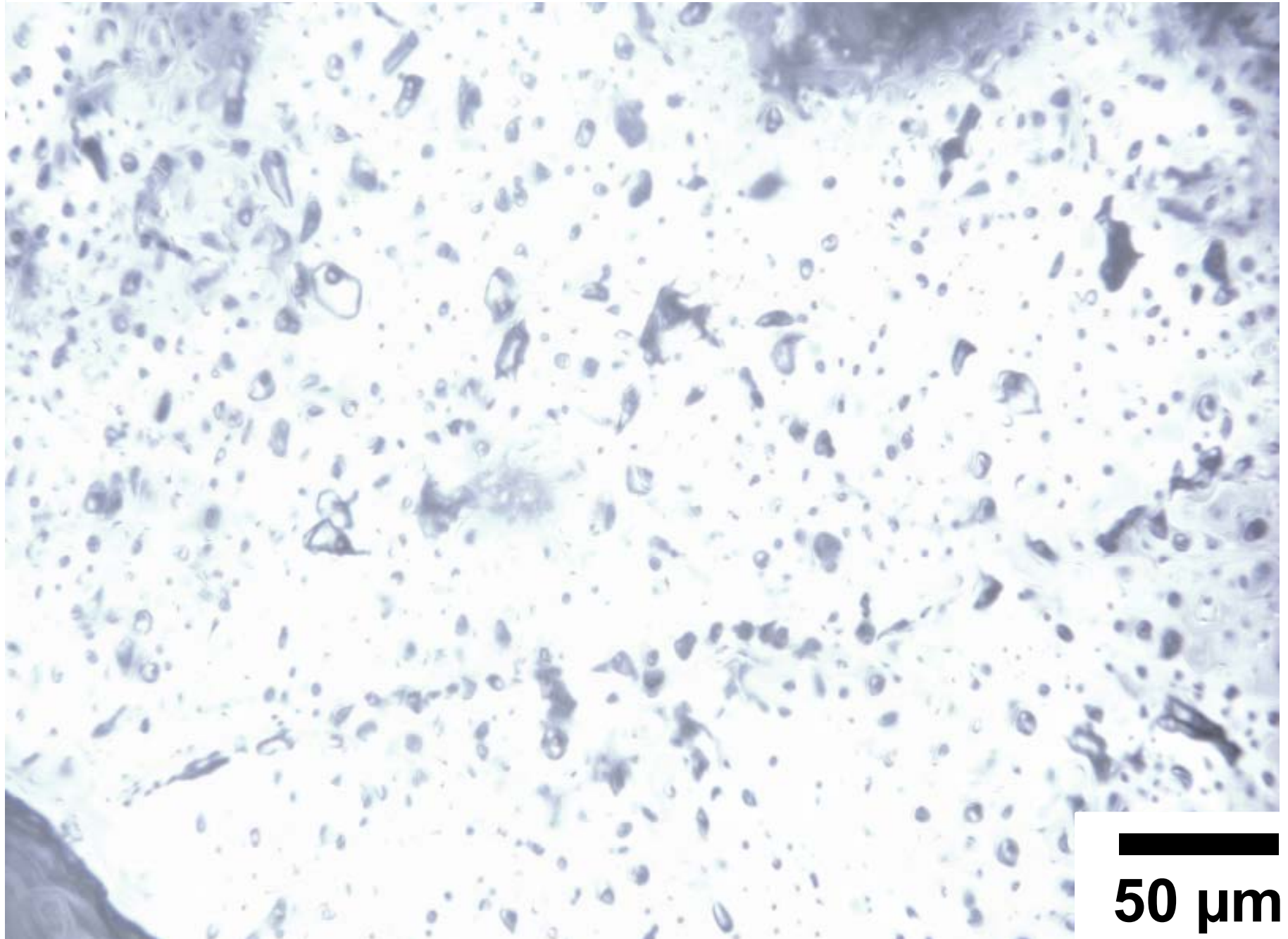
Distribution des veines et des échantillons (n=42)



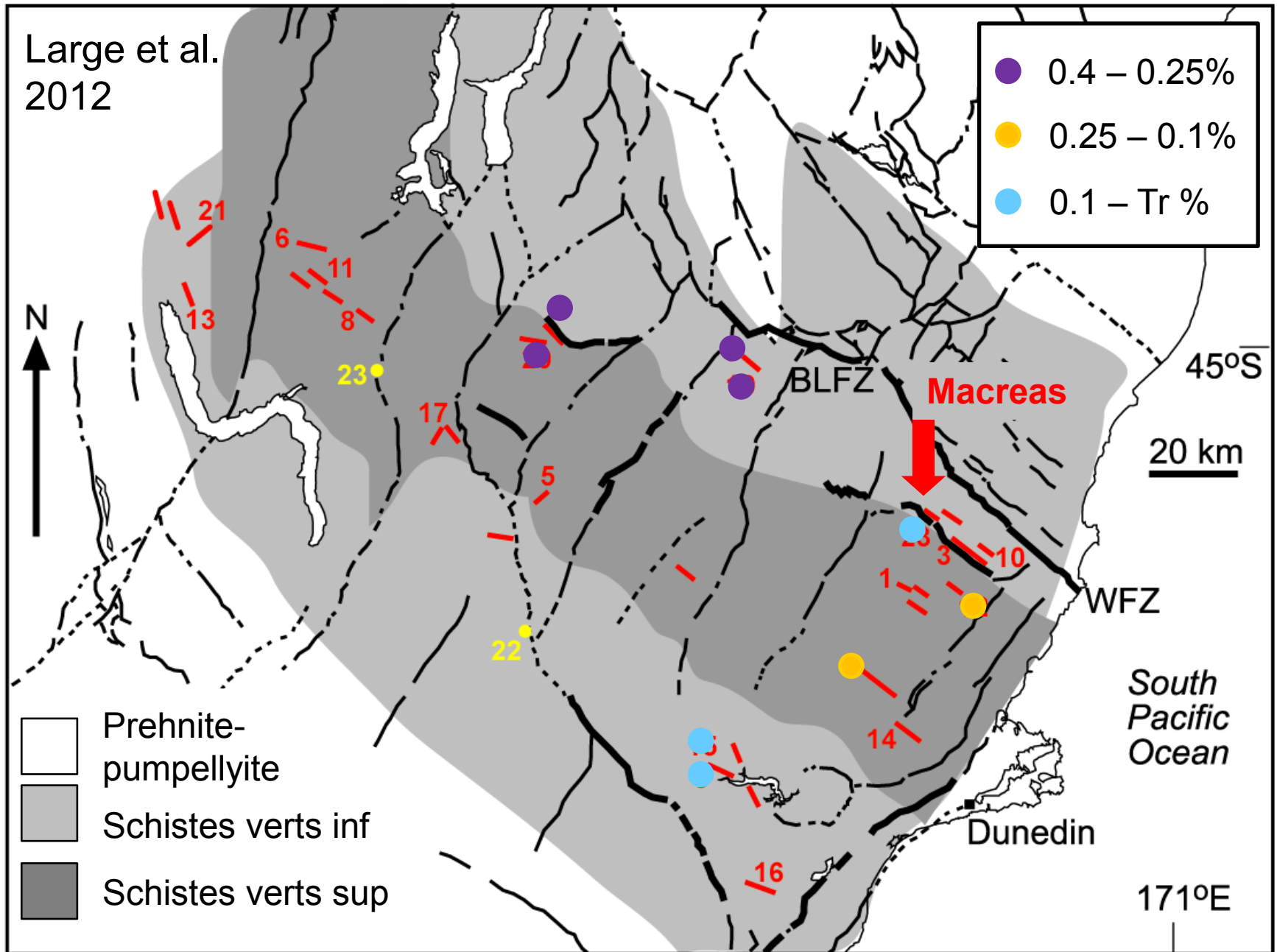
Schiste Otago - C₂H₆ présent



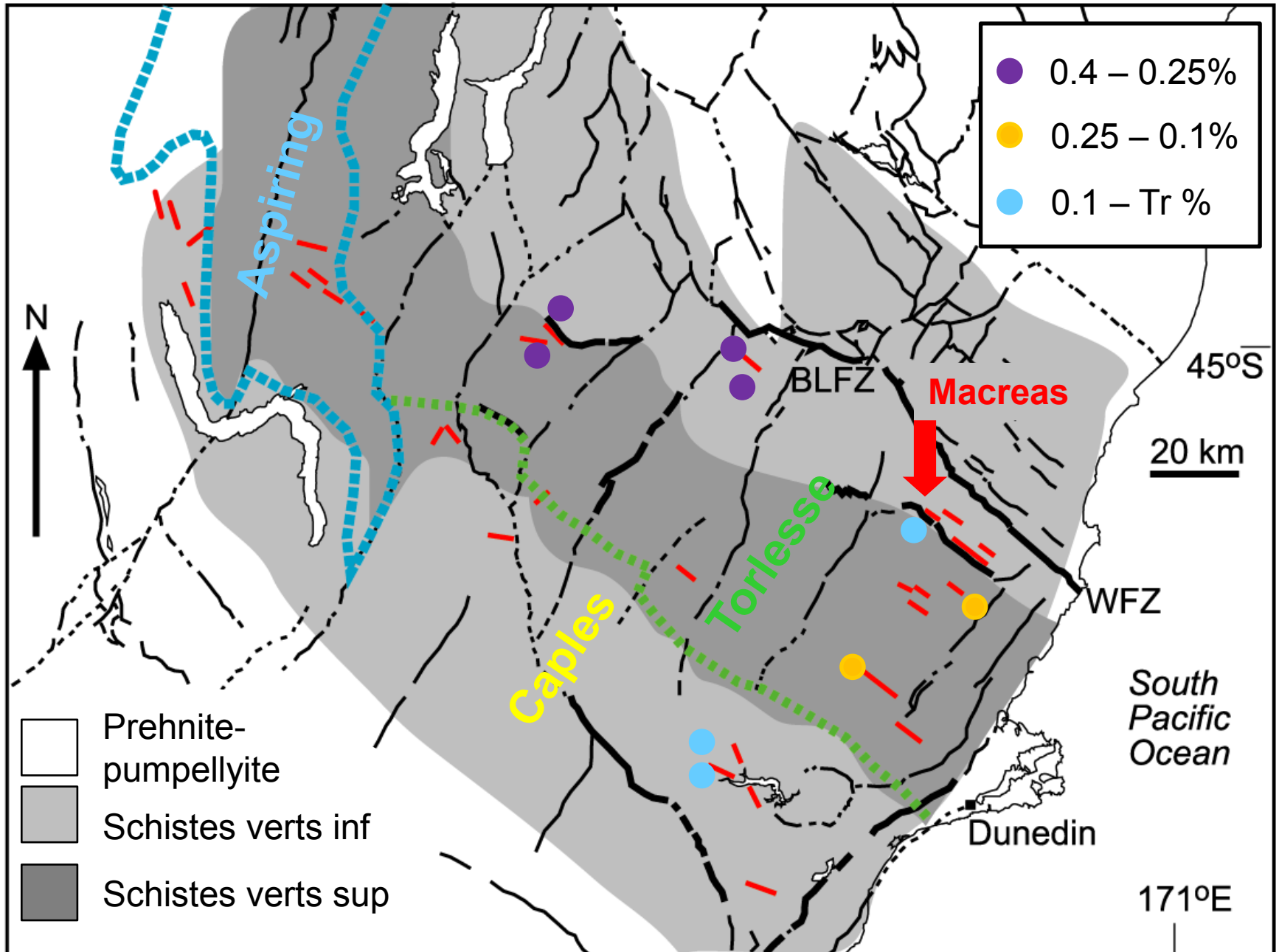
Dominance d'inclusions aqueuses (2 phases)



Distribution et mole % en C_2H_6

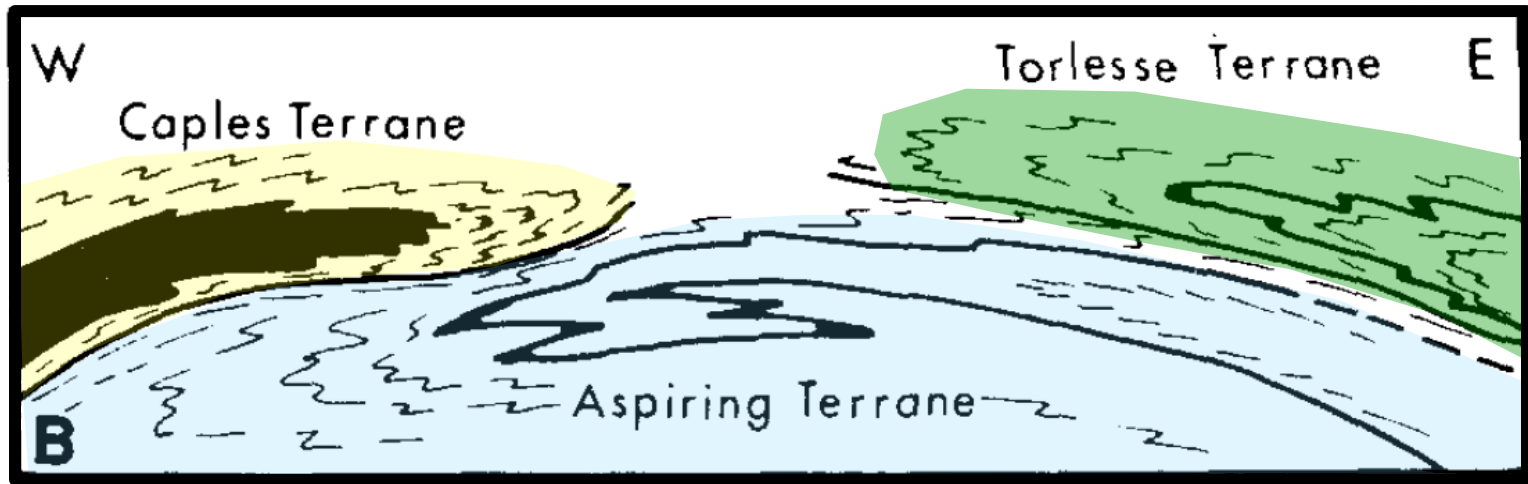


Distribution et mole % en C₂H₆ et terranes



Nappes de chevauchement

Craw & Norris (1991)



Caples

Aspiring

Torlesse

Grès volcanogénique
« andésitique-dacitique »
Avant-arc: accrétion

Adams et al. (2009)

Peu de matière organique

Histoire tecto
différente

Grès quarzo-feldspatique
Argilite grise à noir
Turbidites
Dépôt flysch

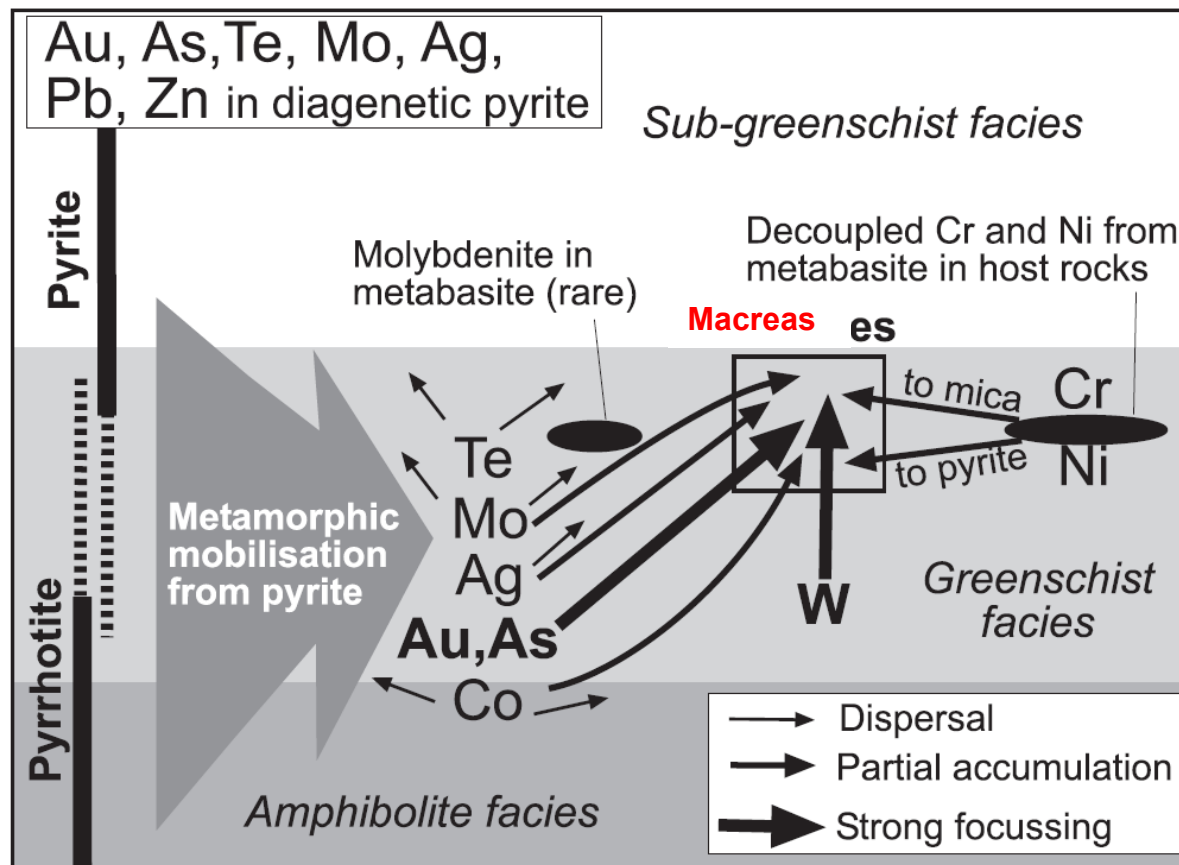
Mackinnon (1983)

Plus riche matière organique

Implications

Validation du concept

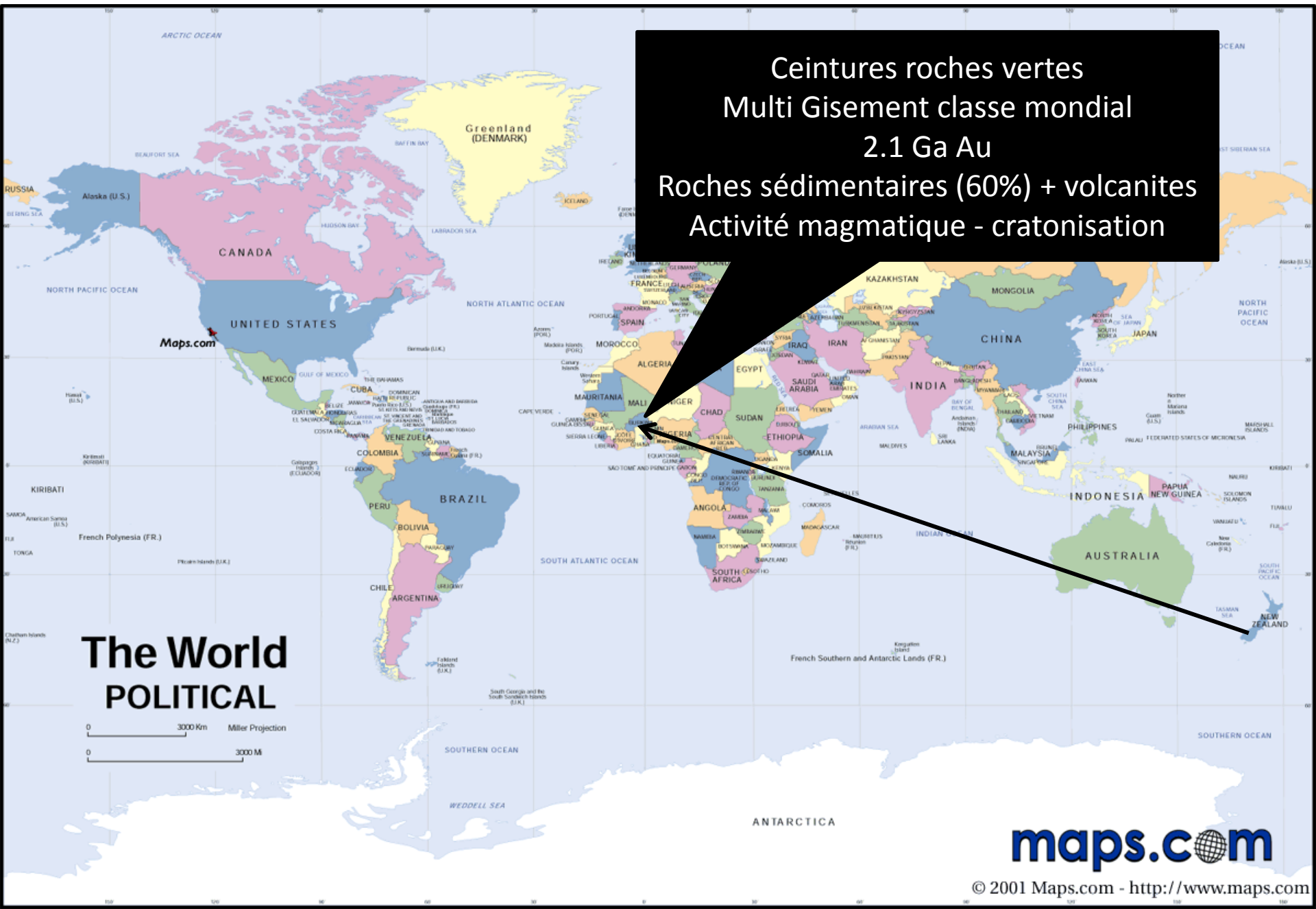
Sélection d'un territoire + fertile



Large et al., 2012

Localisation des champs aurifères orogéniques

Ceintures roches vertes
Multi Gisement classe mondiale
2.1 Ga Au
Roches sédimentaires (60%) + volcanites
Activité magmatique - cratonisation



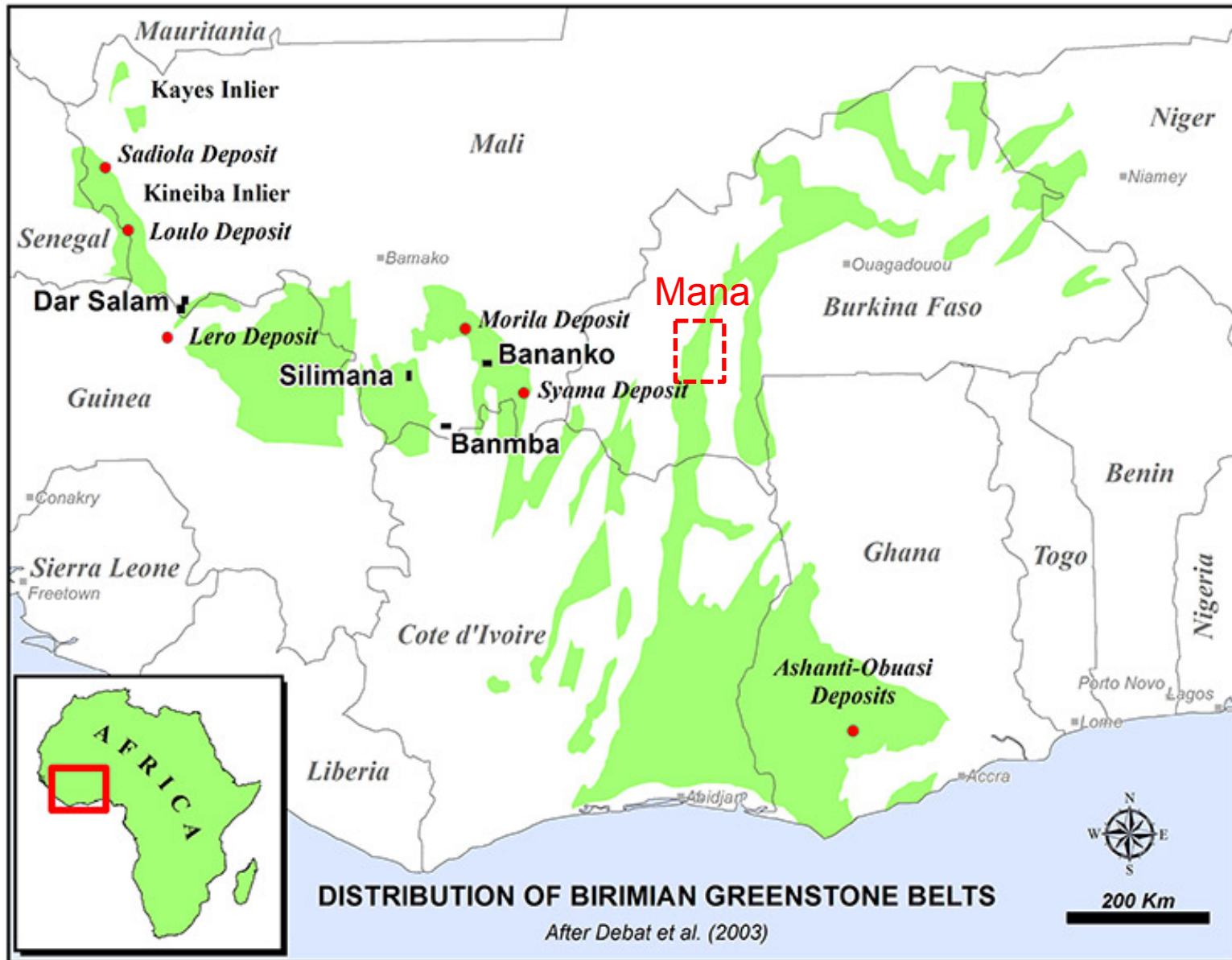
The World
POLITICAL

0 3000 Km
0 3000 M
Miller Projection

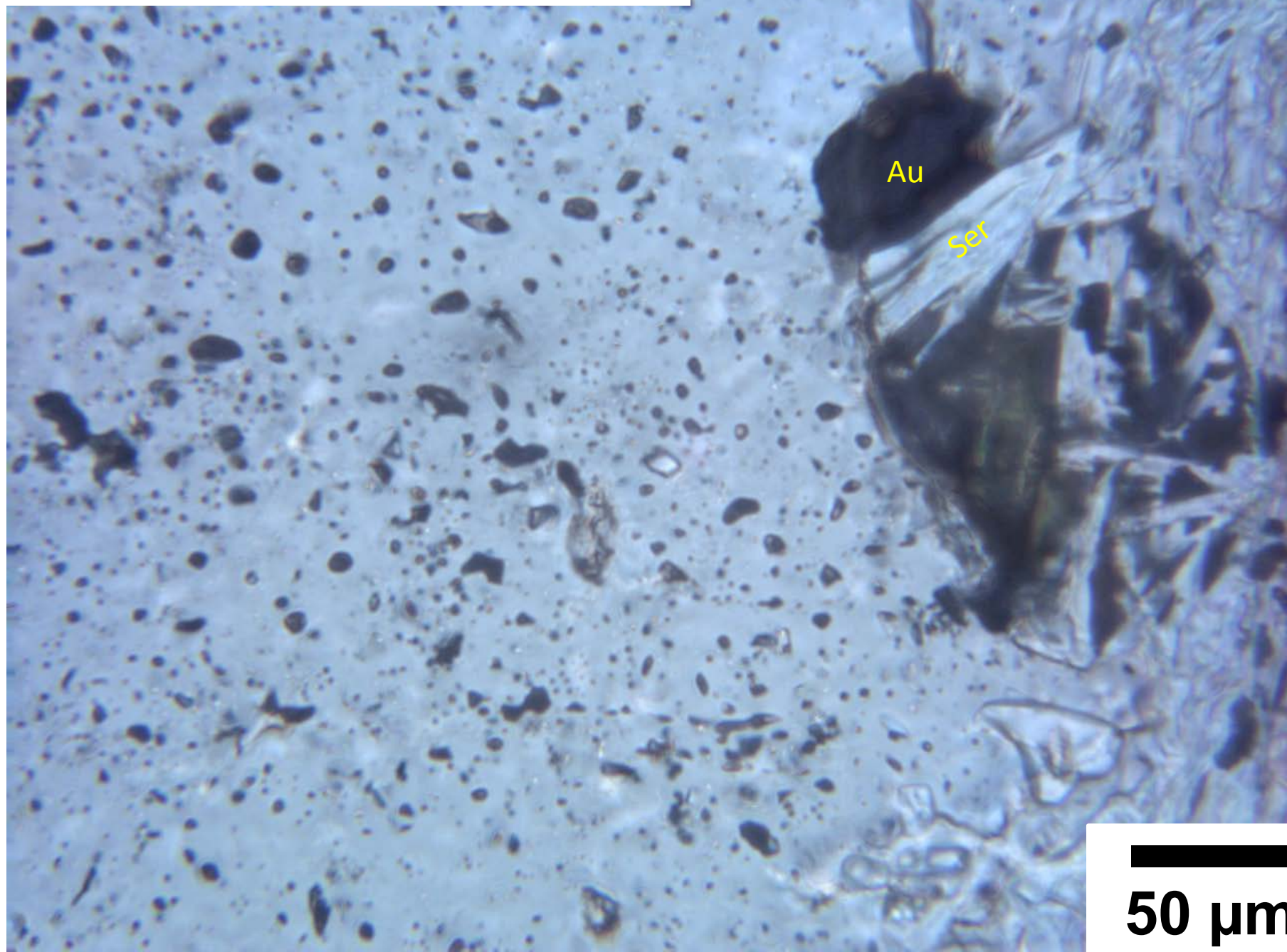
maps.com

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Localisation des ceintures et du district de Mana

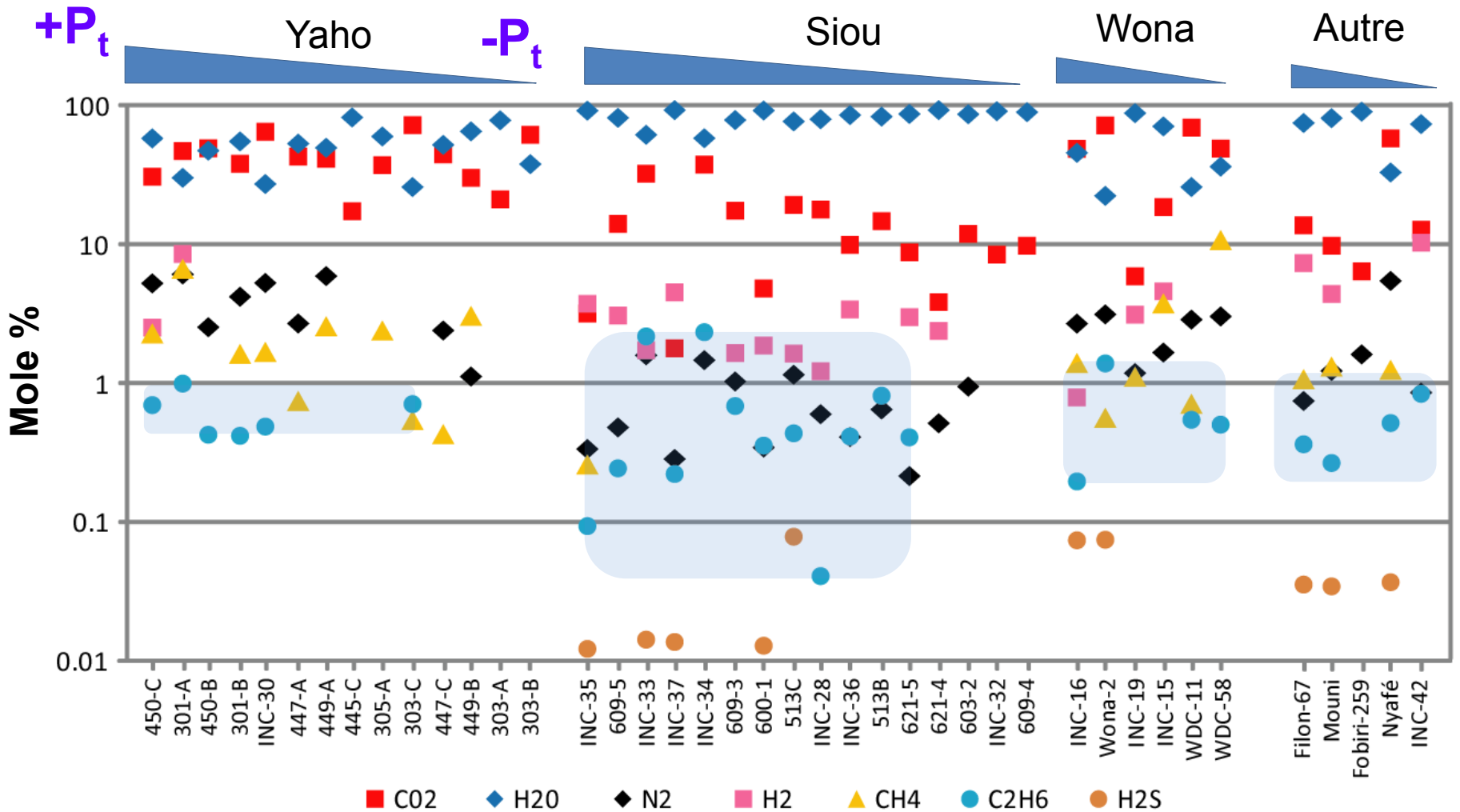


Variété de type IF: 513B



50 μm

Mana district - C₂H₆ Omniprésent



Modifiée de Gaboury, 2013

Implications

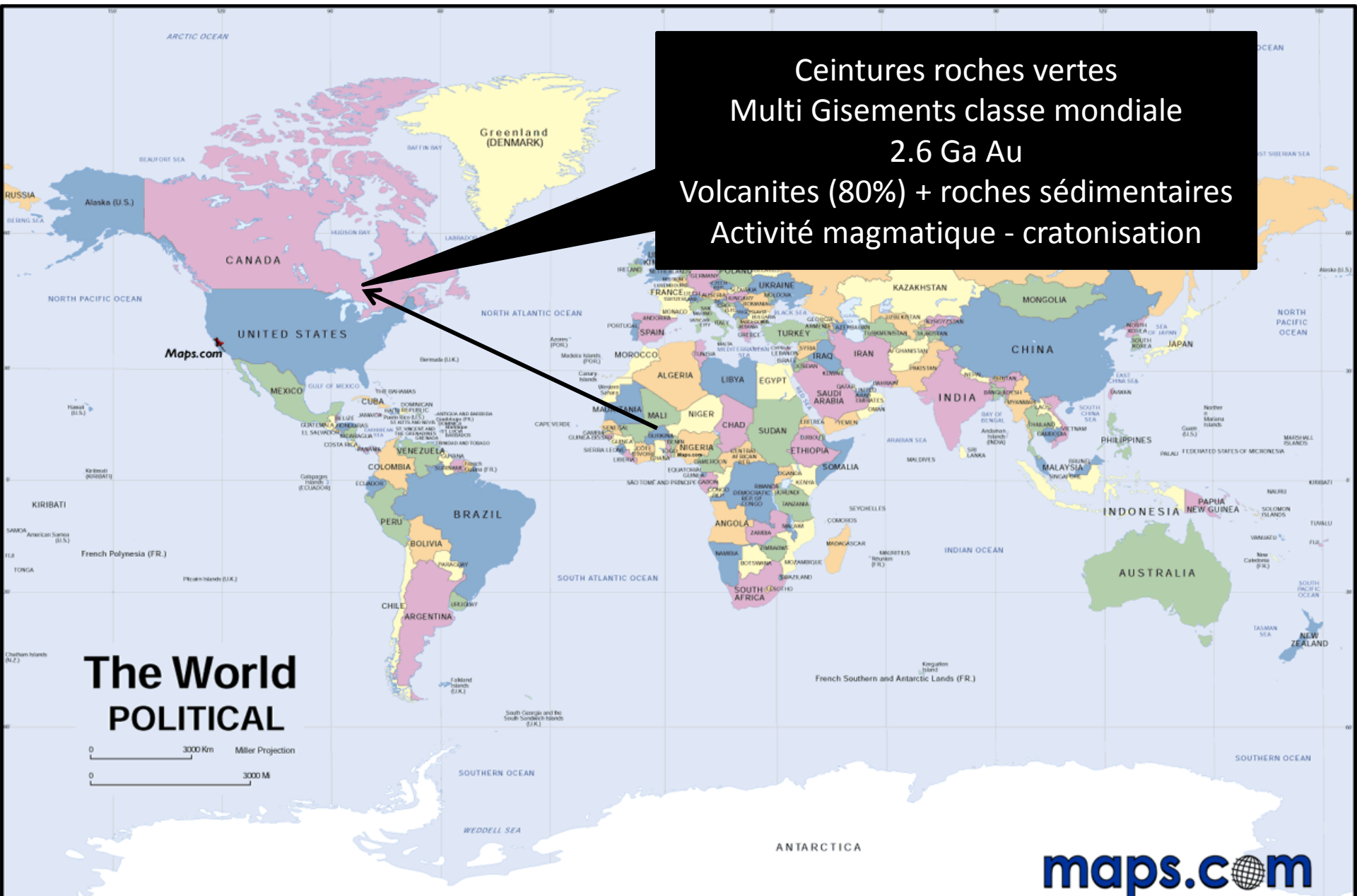
Validation du concept

Shale à graphite et pyrite nodulaire dans l'empilement



Localisation des champs aurifères orogéniques

Ceintures roches vertes
Multi Gisements classe mondiale
2.6 Ga Au
Volcanites (80%) + roches sédimentaires
Activité magmatique - cratonisation



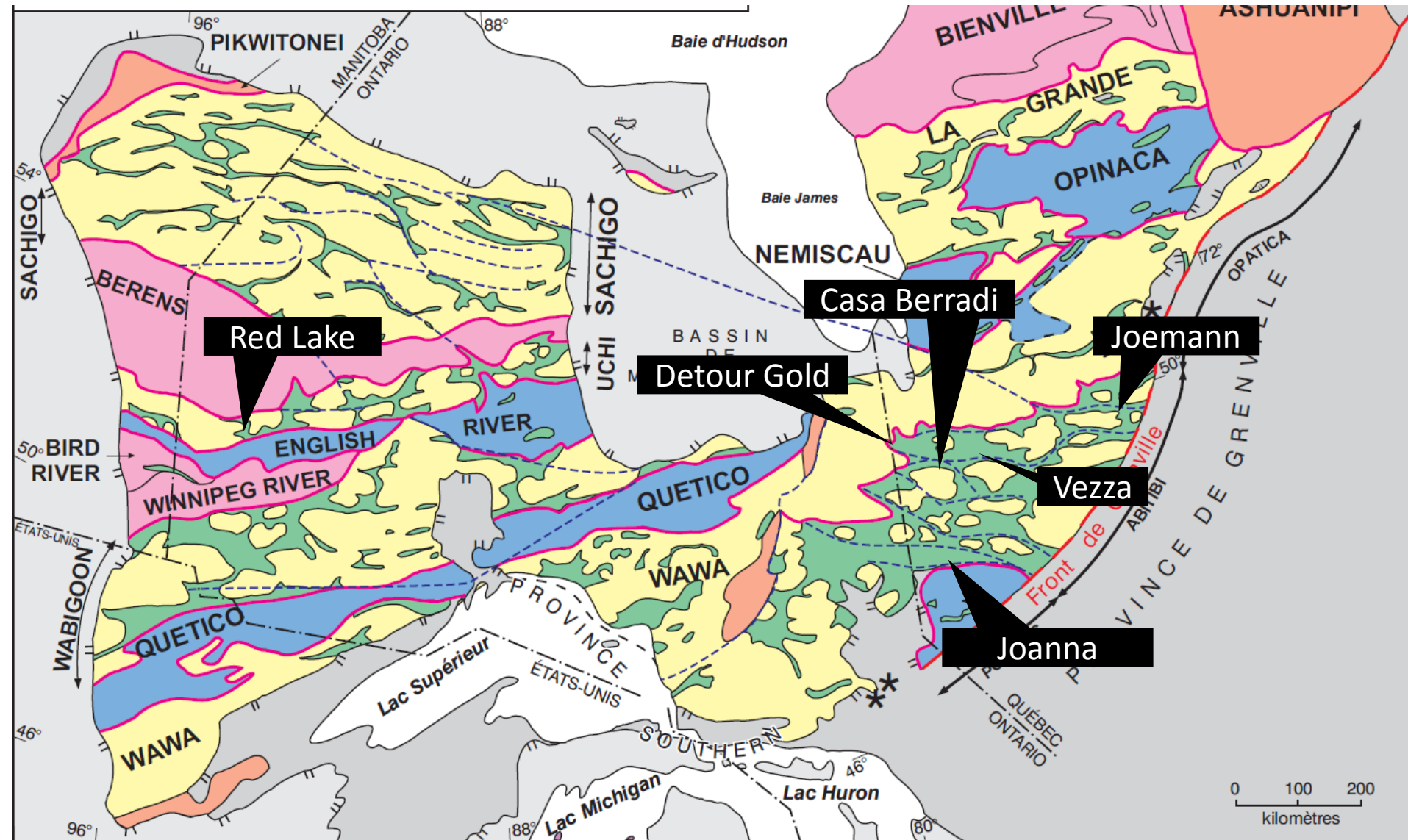
The World
POLITICAL

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maps.com

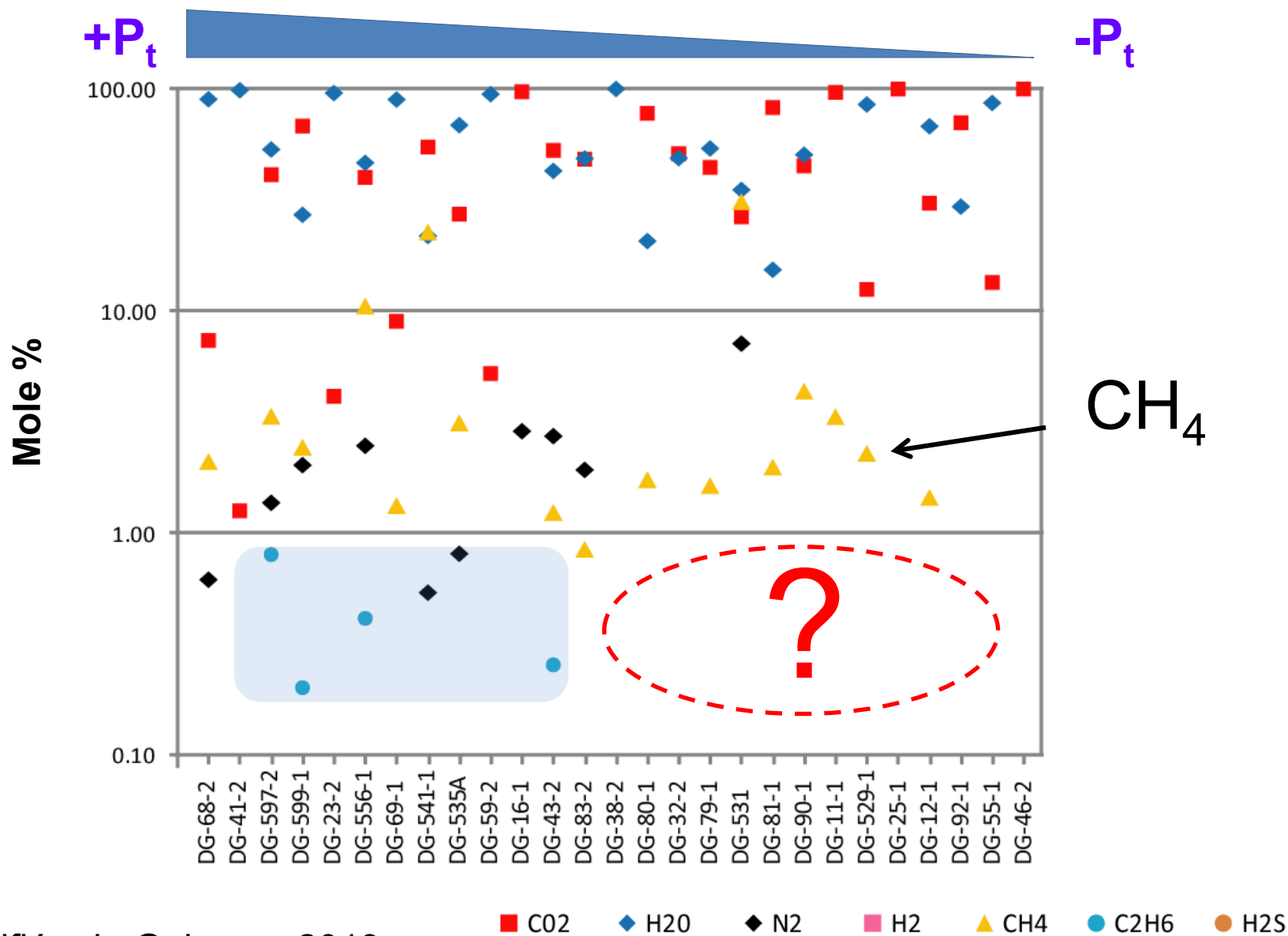
© 2001 Maps.com - <http://www.maps.com>

Au Canada: gisements avec C₂H₆



Source: Géologie Québec, 2004

Detour Gold (~16 Moz Au) - C₂H₆ présent

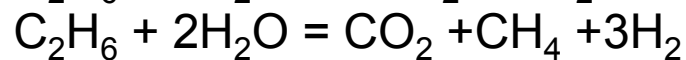
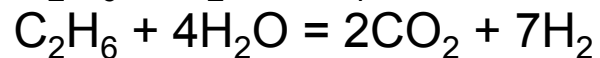
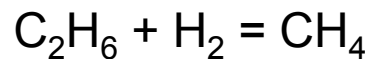


Modifiée de Gaboury, 2013

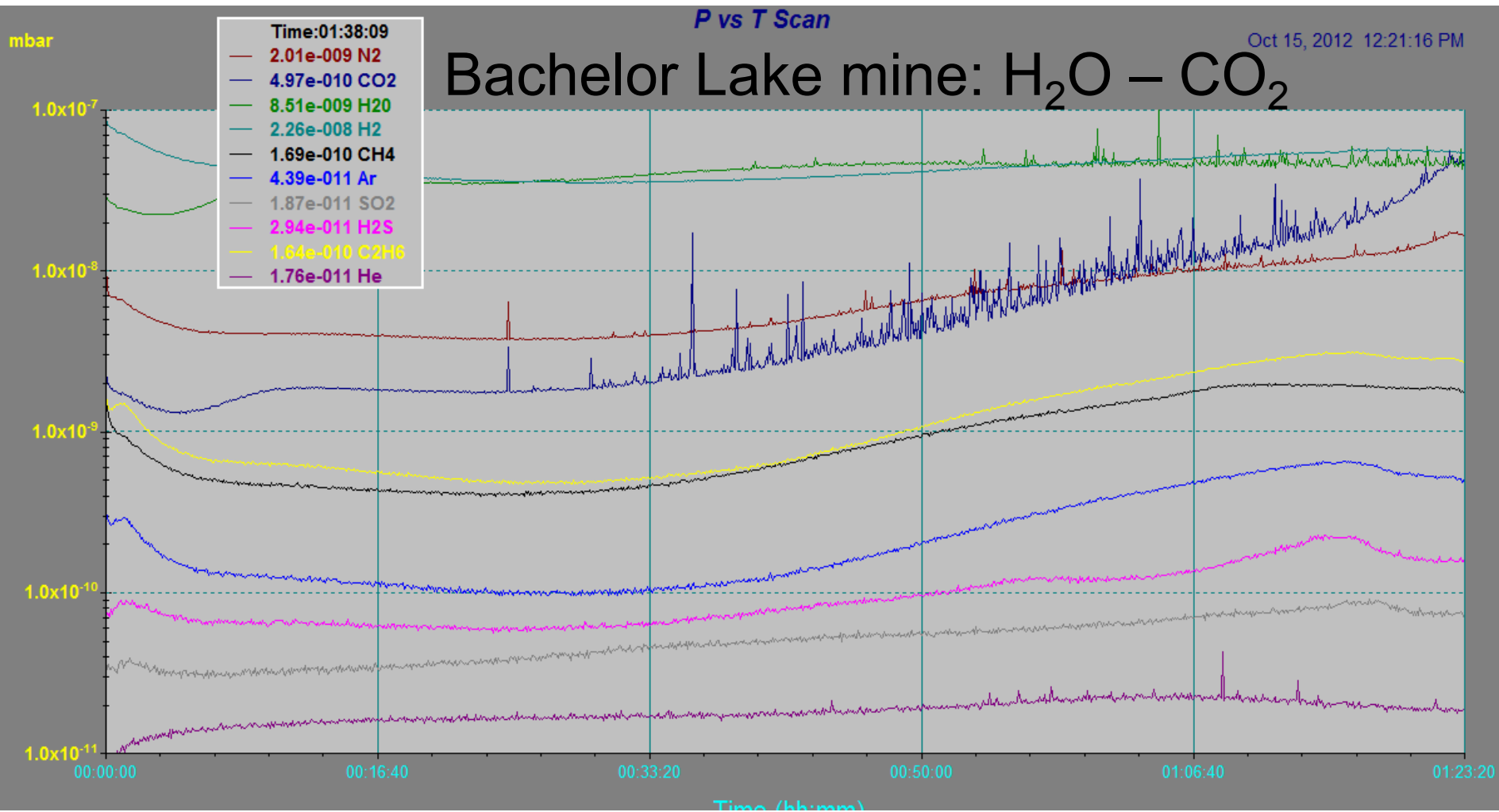
Ethane = indicateur absolu

Absence ≠ discriminant

Dégradation de l'éthane

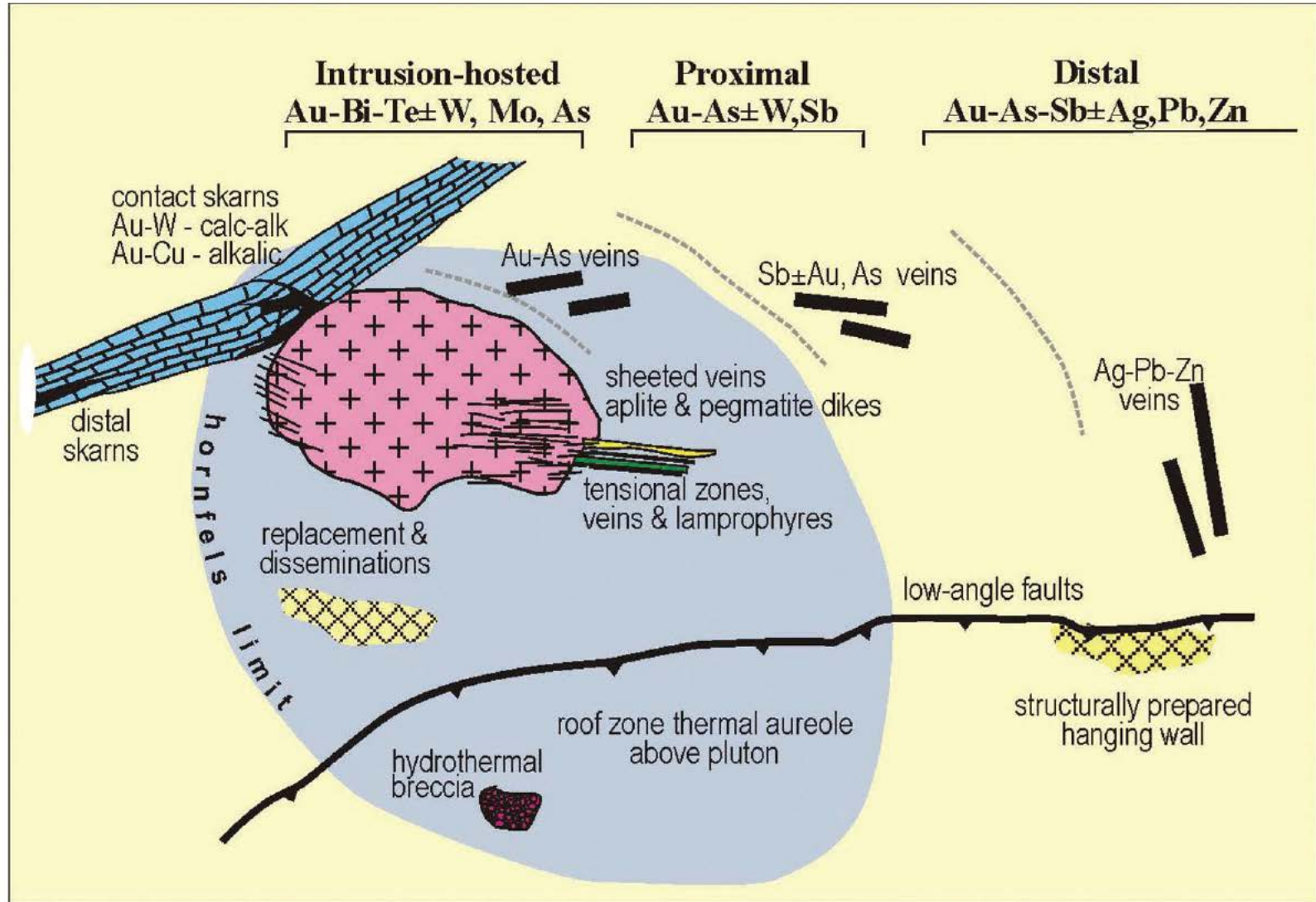


Gaboury, 2013



Modèle Au magmatique

Signature métallique: Au, Ag, Bi, Te, As, Cu, Sb, Pb



Cartographie au LA-ICP-MS

Pyrite Yaho 305-B

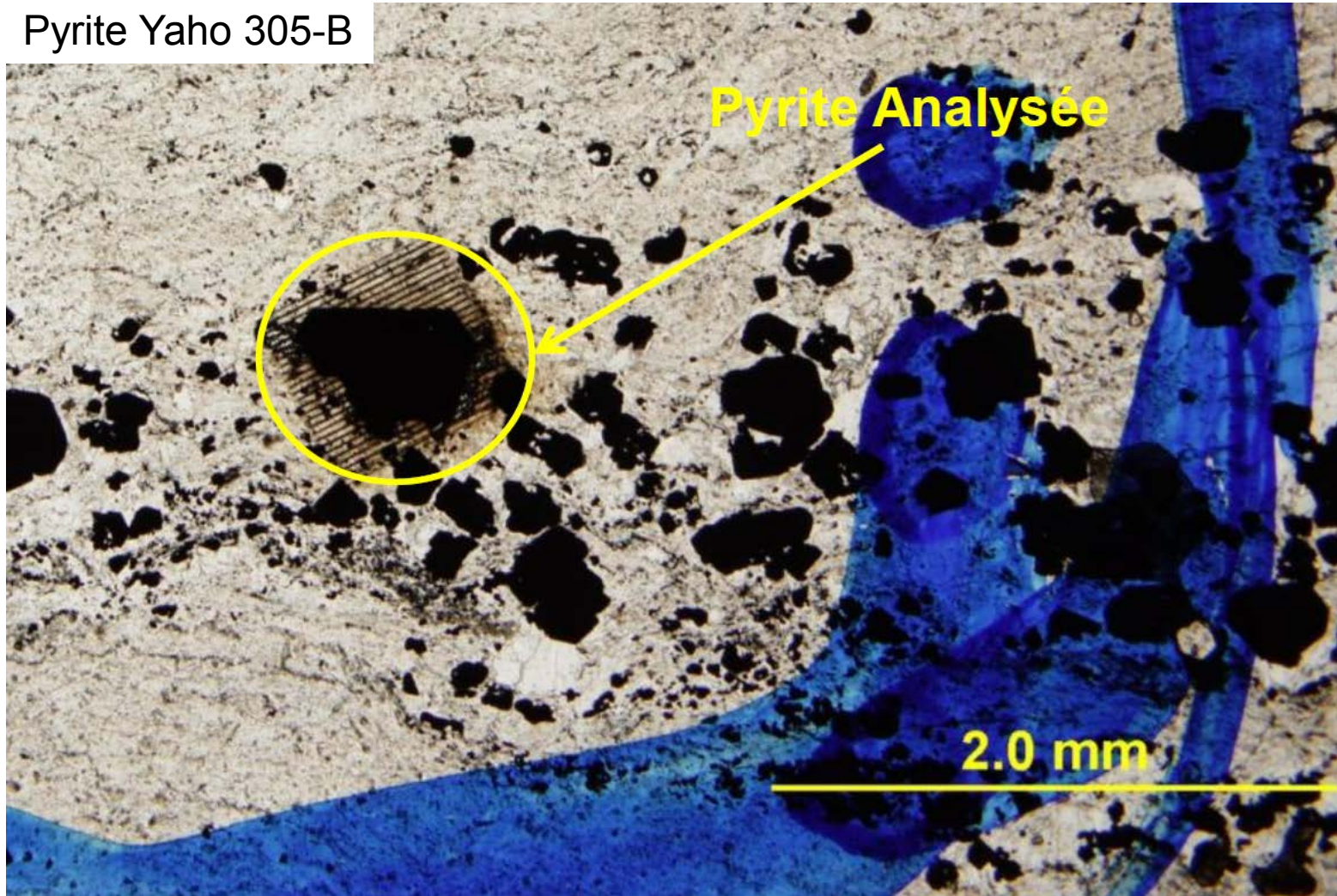


Photo tirée de Mercier, 2013

LA-ICP-MS (new: 2012)



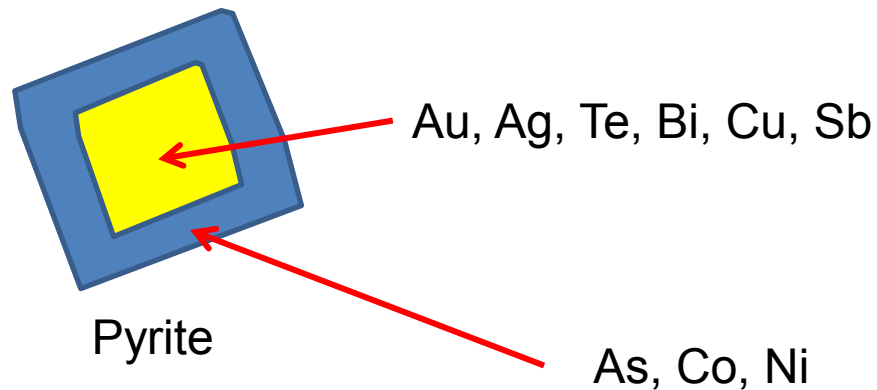
Résolution M-50
Excimer (193nm) ArF
de Resonetics

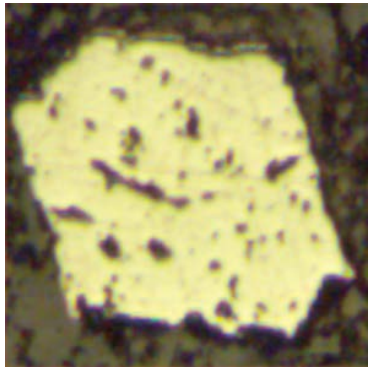


Modèle 7700x de Agilent

Approche conceptuelle

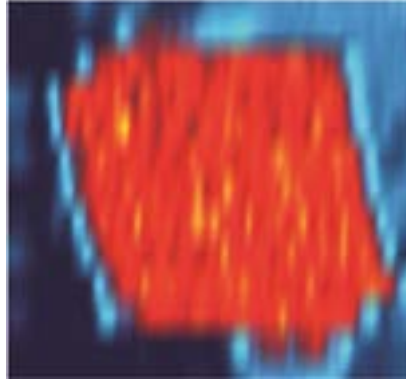
- Déterminer les associations de métaux en lien avec l'or
- Affilier les associations de métaux en termes de sources
- Établir l'histoire chronologique pour déterminer des processus



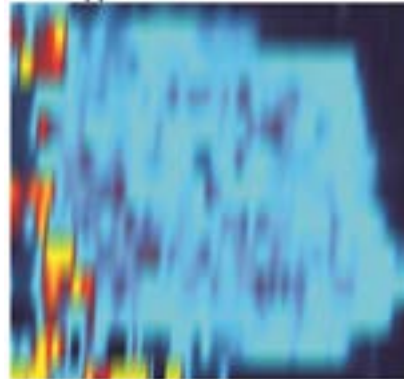


0.2 mm

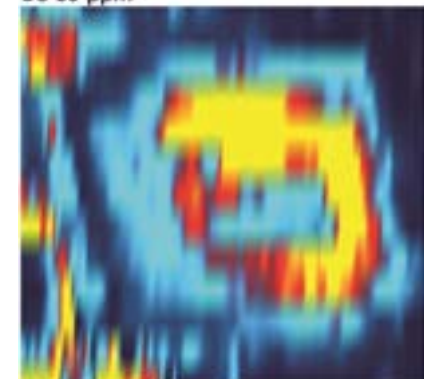
Fe 57 CPS



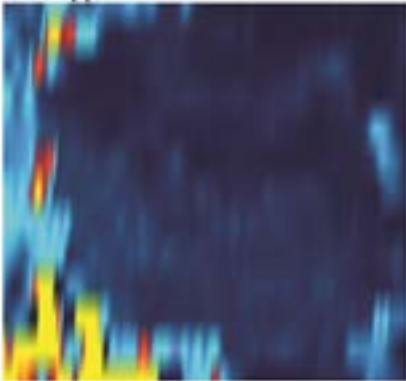
As 75 ppm



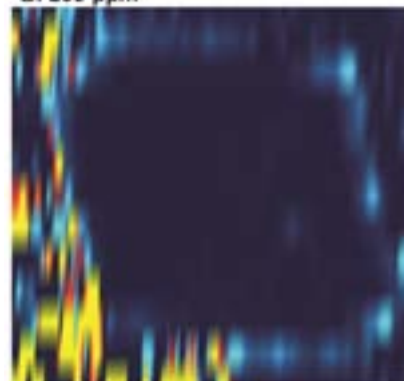
Co 59 ppm



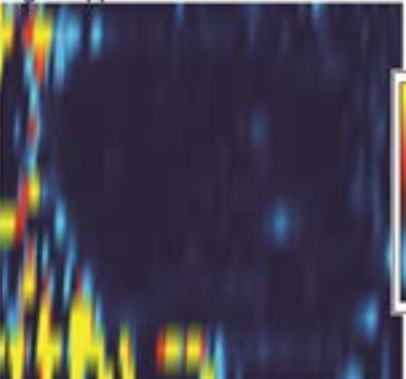
Ni 60 ppm



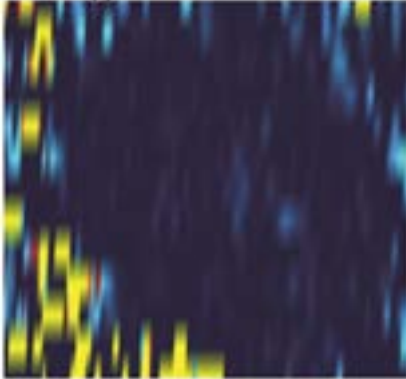
Bi 209 ppm



Ag 107 ppm

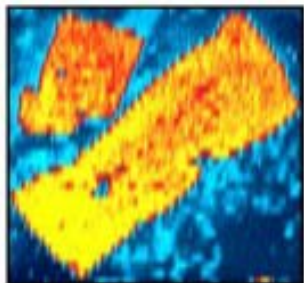


Au 197 ppm

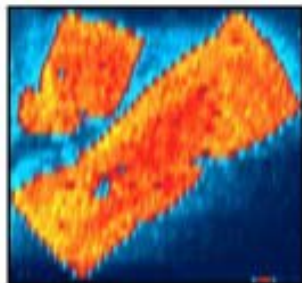


As, Co, Ni ± Bi

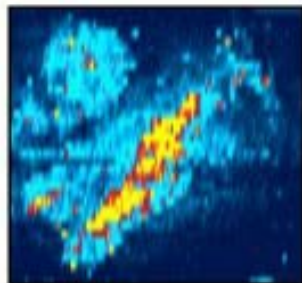
Au, Ag



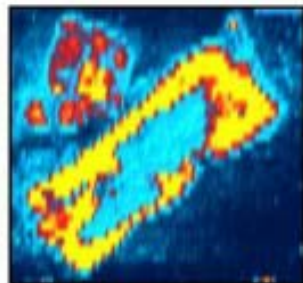
Fe 57



S 33



Au 197

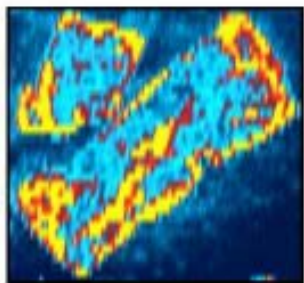


As 75

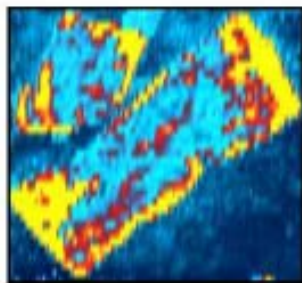


0.5 mm

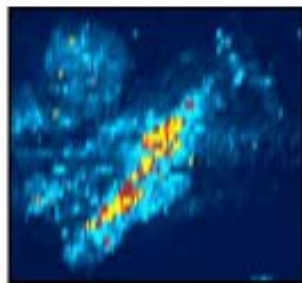
M513-B



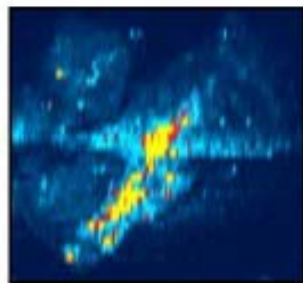
Co 59



Ni 60



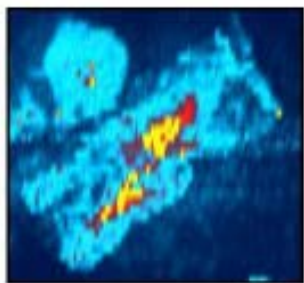
Ag 107



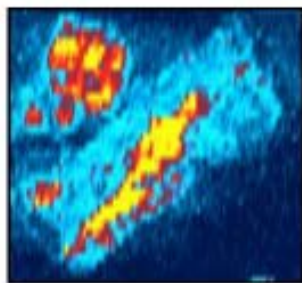
Cu 65

Coeur

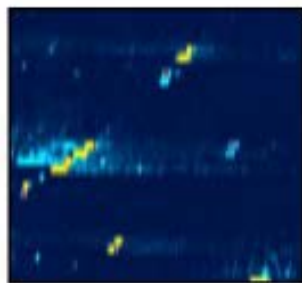
Au, Ag, Te, Bi, Pb,
Cu, Sb



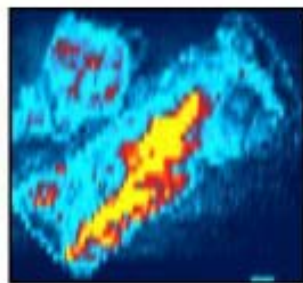
Pb 208



Te 125



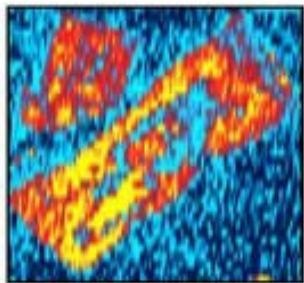
Mo 95



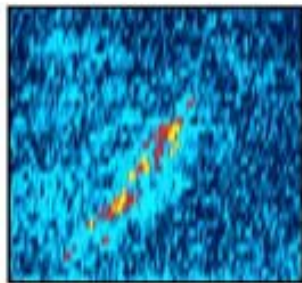
Bi 209

Rim

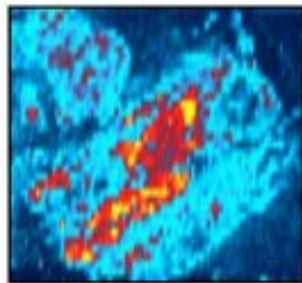
As, Ni, Co, Se



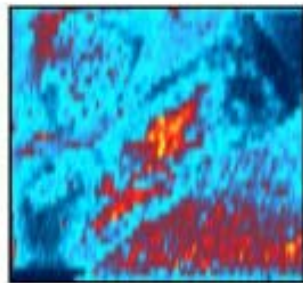
Se 82



Hg 202



Sb 121



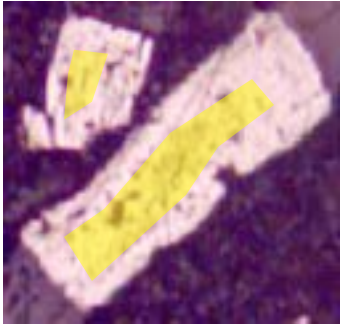
V 51

J-F Dupuis 2013

Interprétation préliminaire

2 possibilités

Factuellement



Fluide précocé (F1):

Au, Ag, Te, Bi, Pb,
Cu, Sb

$Au/Ag = 0.1 - 0.4$

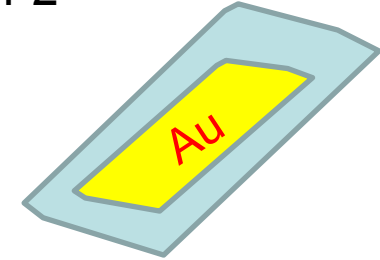
Magmatique

Fluide tardif (F2):

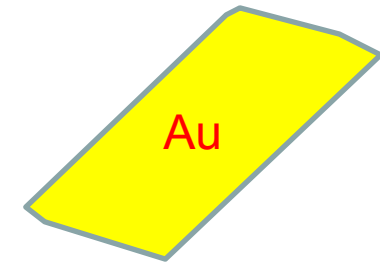
As, Co, Ni, Se

Source ultramafique
ou shale

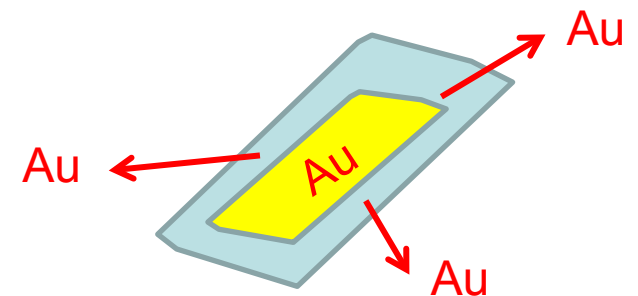
Croissance successive
F1 et F2



Croissance complète F1

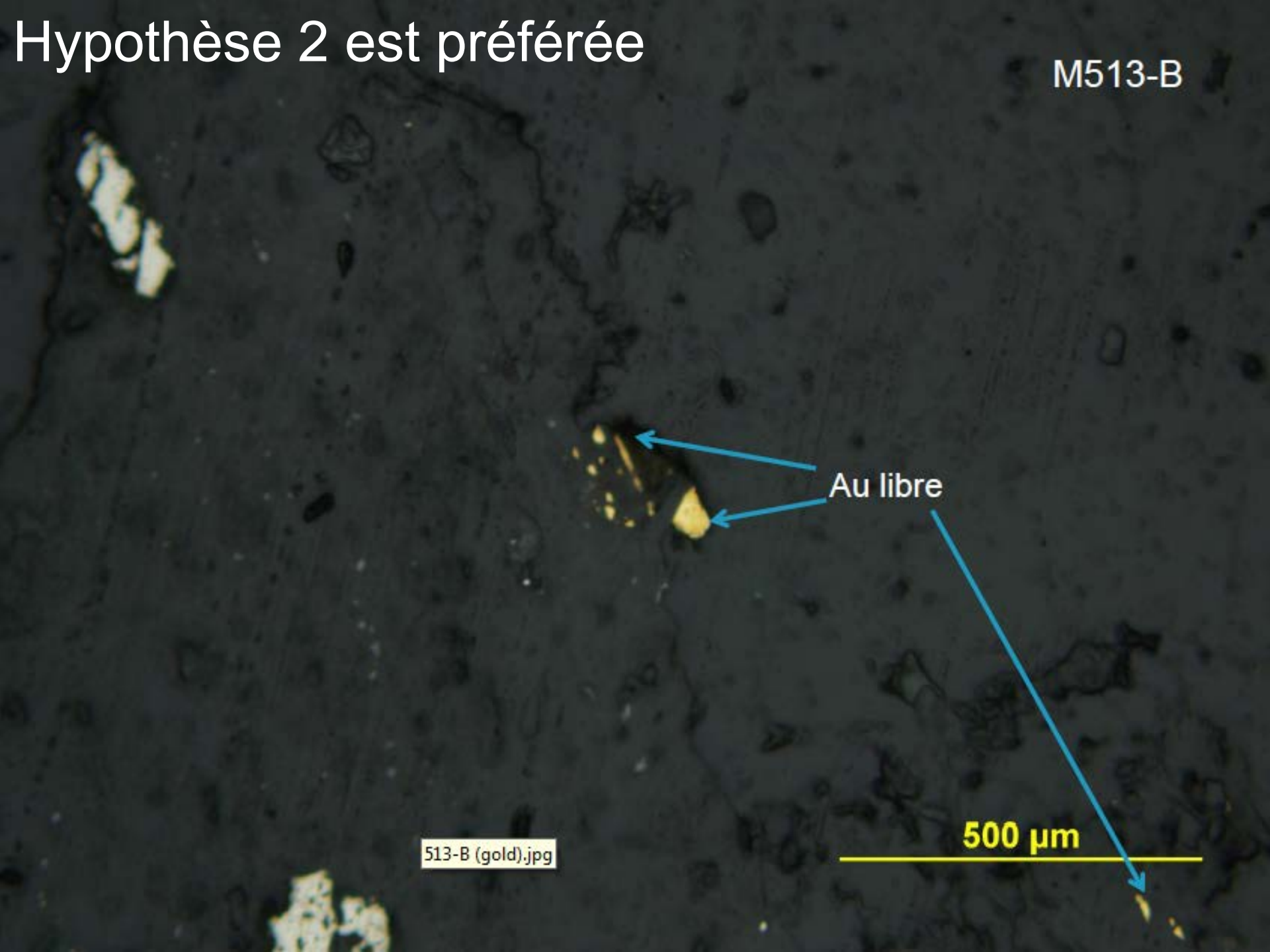


Corrosion du rim avec F2



Hypothèse 2 est préférée

M513-B

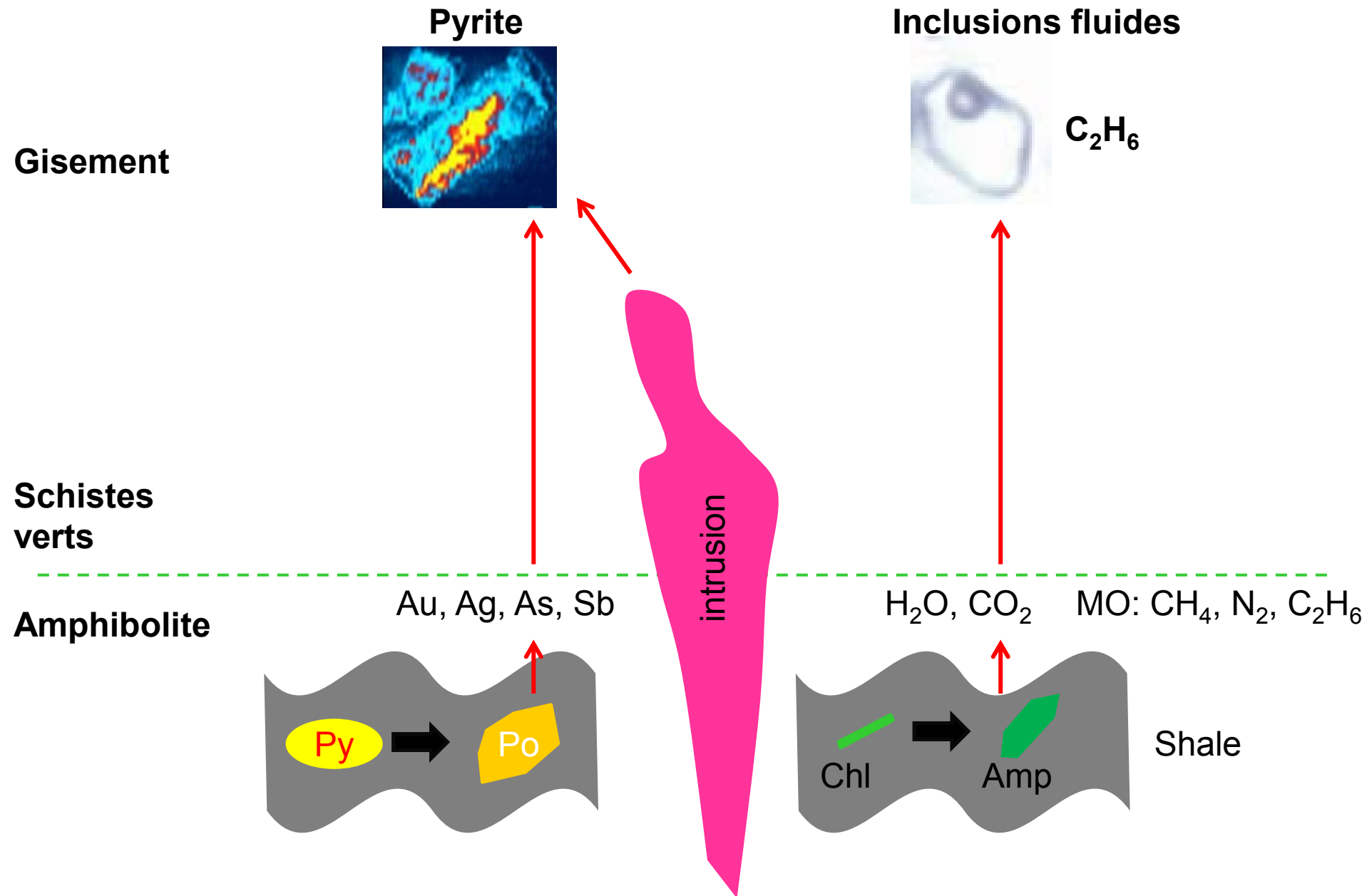


Au libre

500 μm

513-B (gold).jpg

Couplage pyrites - volatiles: sources Au



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