CIM Saskatoon, January 21 2009

Gold prospectivity of major deformation zones in the Abitibi subprovince

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Photo: Sigma-Lamaque gold mine, Quebec, ca. 1920.

CONSOREM?

- A non-profit research organization which represents a link between different members and partners of the mineral industry in Quebec:
  - Mineral exploration companies (industrial members)
  - Federal and provincial governments
  - Universities - UQAM – Montreal, UQAC – Chicoutimi - UQAT – Rouyn-Noranda
  - Funded by the governments (~50%) and industrial members (~50%)
  - Four full-time, dedicated researchers based in Montreal and Chicoutimi universities
- Its goal: contribute to the revitalization of the mineral industry in Quebec. How is it done? By:
  - Research projects with strong economic implications. Research themes *are selected (democratically) by industrial members* → Technologies, new exploration models, etc…
  - Knowledge transfer from the academic world to the mineral industry
  - Training of highly qualified personnel in mineral exploration → public conferences, field trips, scolarships and supervision for graduate students…

CONSOREM?

CONSOREM

Mineral Exploration
Research Consortium

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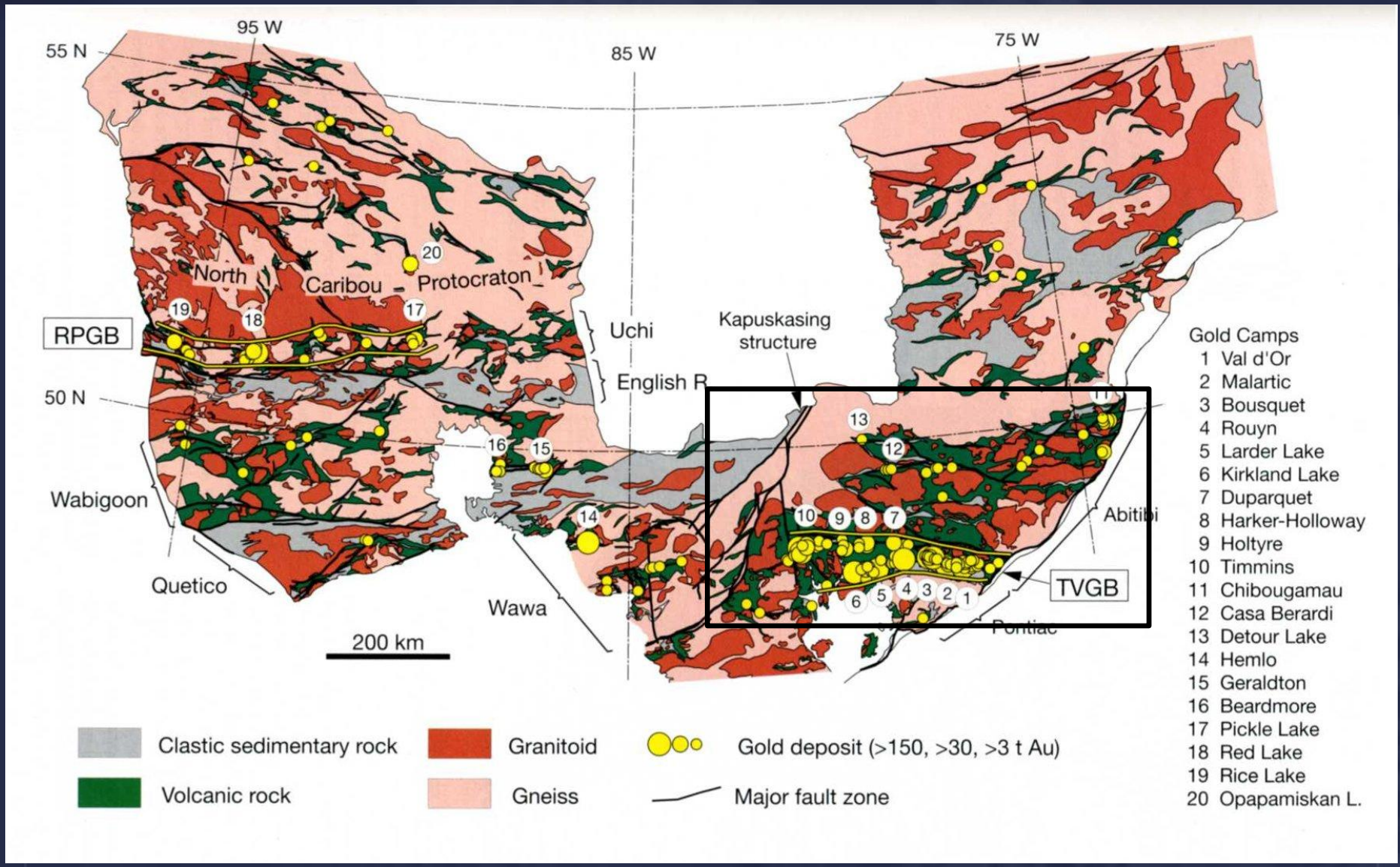
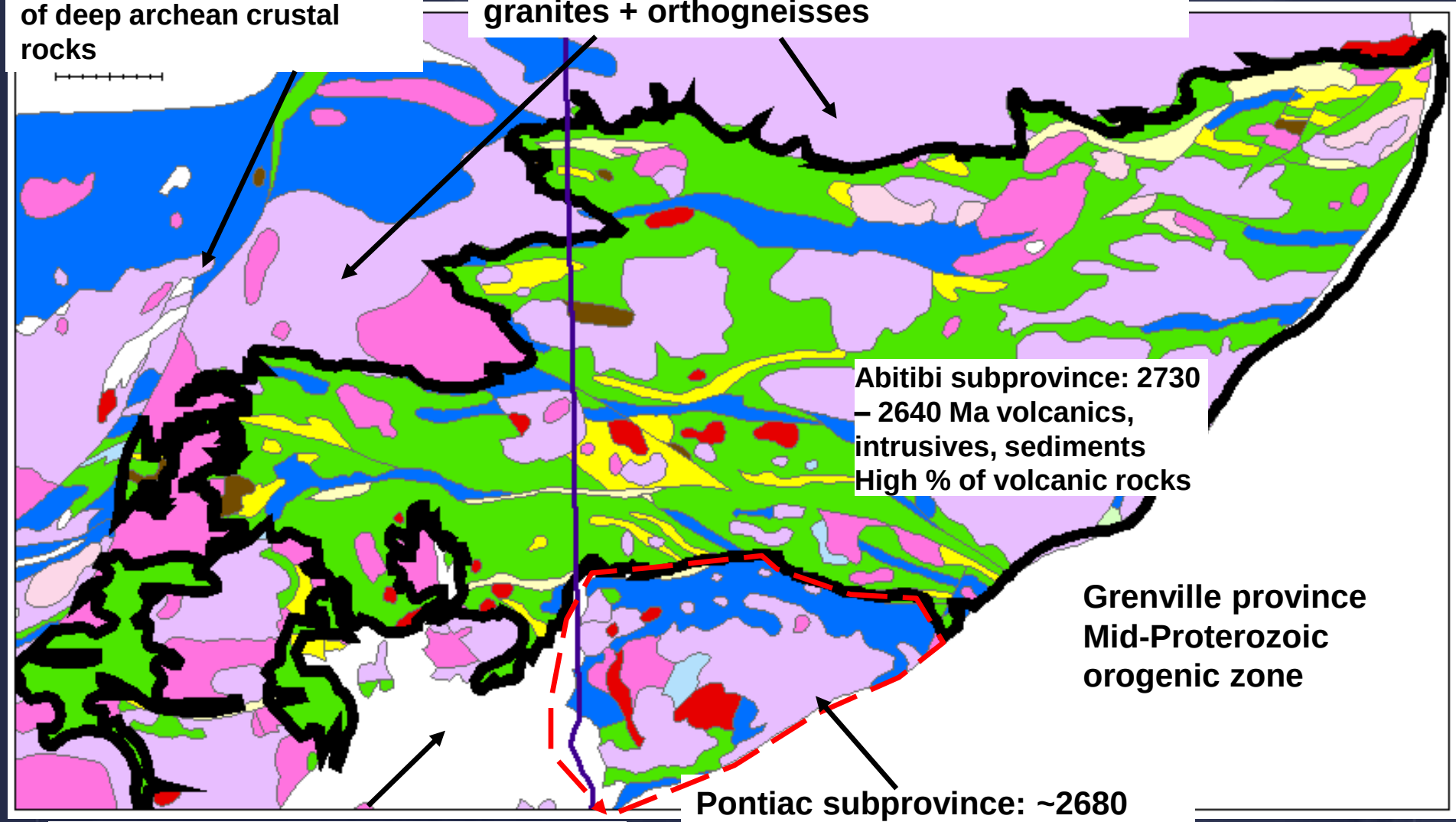
The Abitibi subprovince



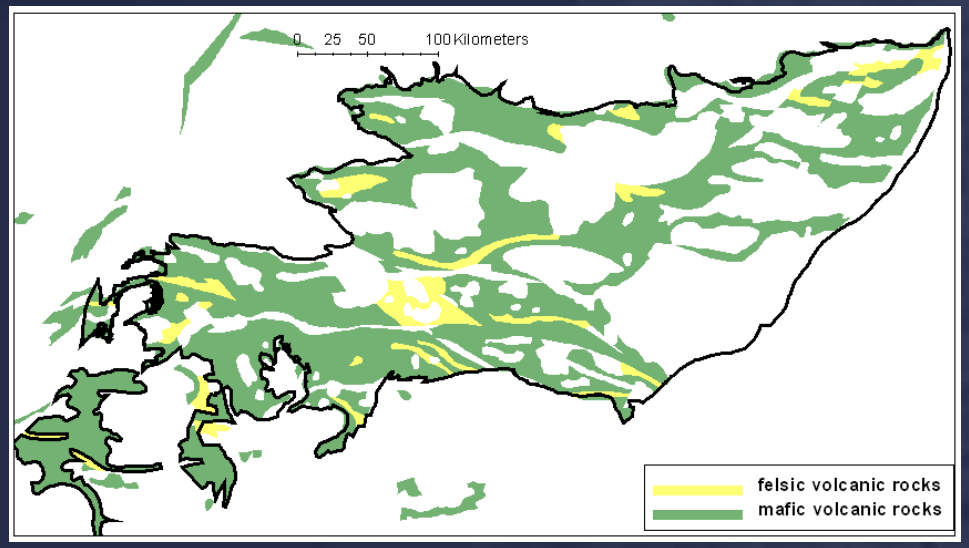
From Robert et al., 2005.

The Abitibi subprovince: boundaries

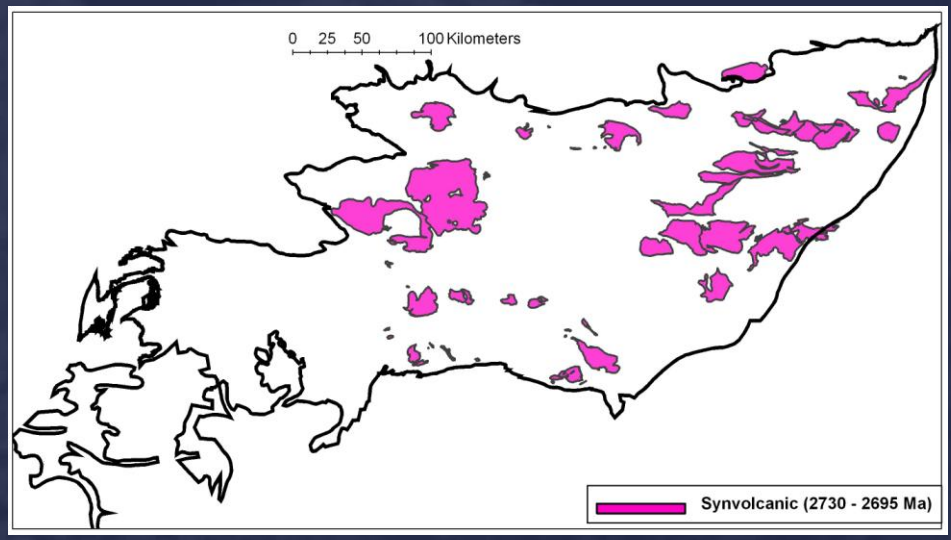


The Abitibi subprovince

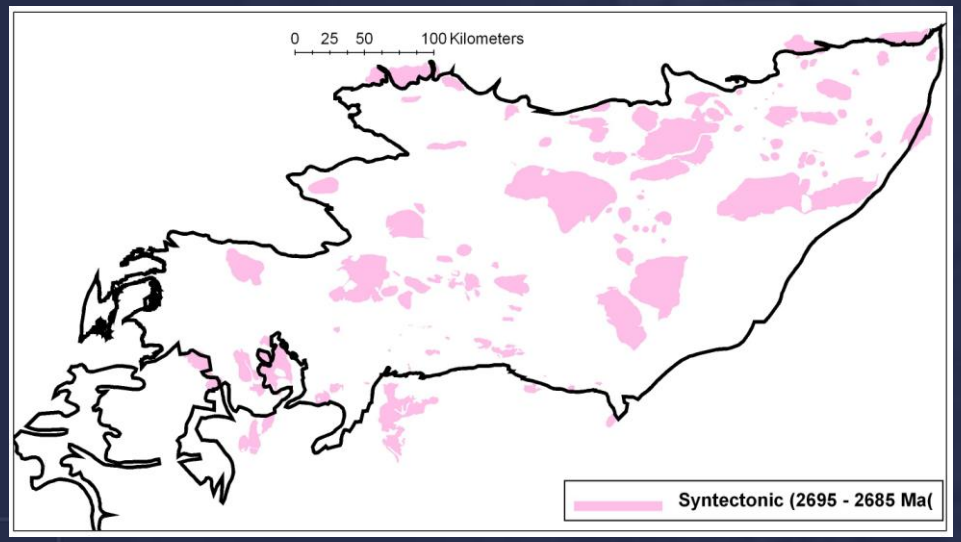
2730 - 2695 Ma mafic and felsic volcanic rocks



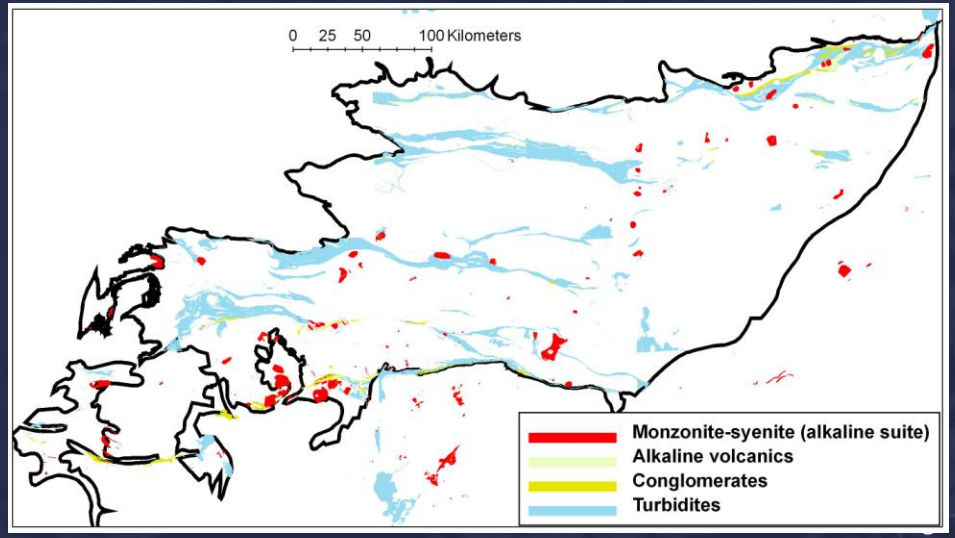
Coeval synvolcanic intrusions (TTG suite)



Mainly 2695 - 2685 Ma syntectonic granodiorites-granites

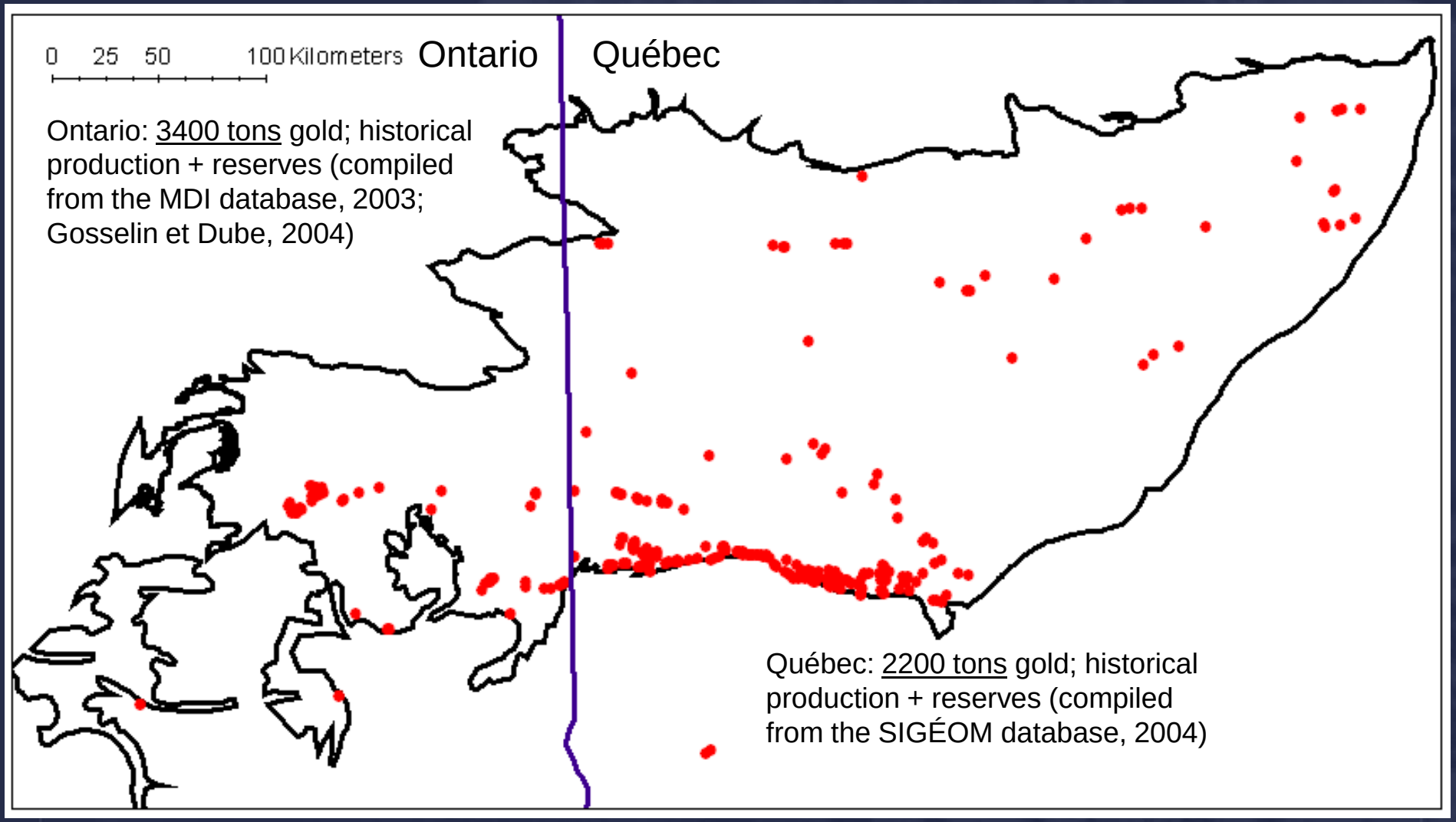


~2695 - 2685 Ma turbidites (blue)
2685 – 2670 Ma conglomerates, monzonite-syenite intrusions and alkalinel volcanics

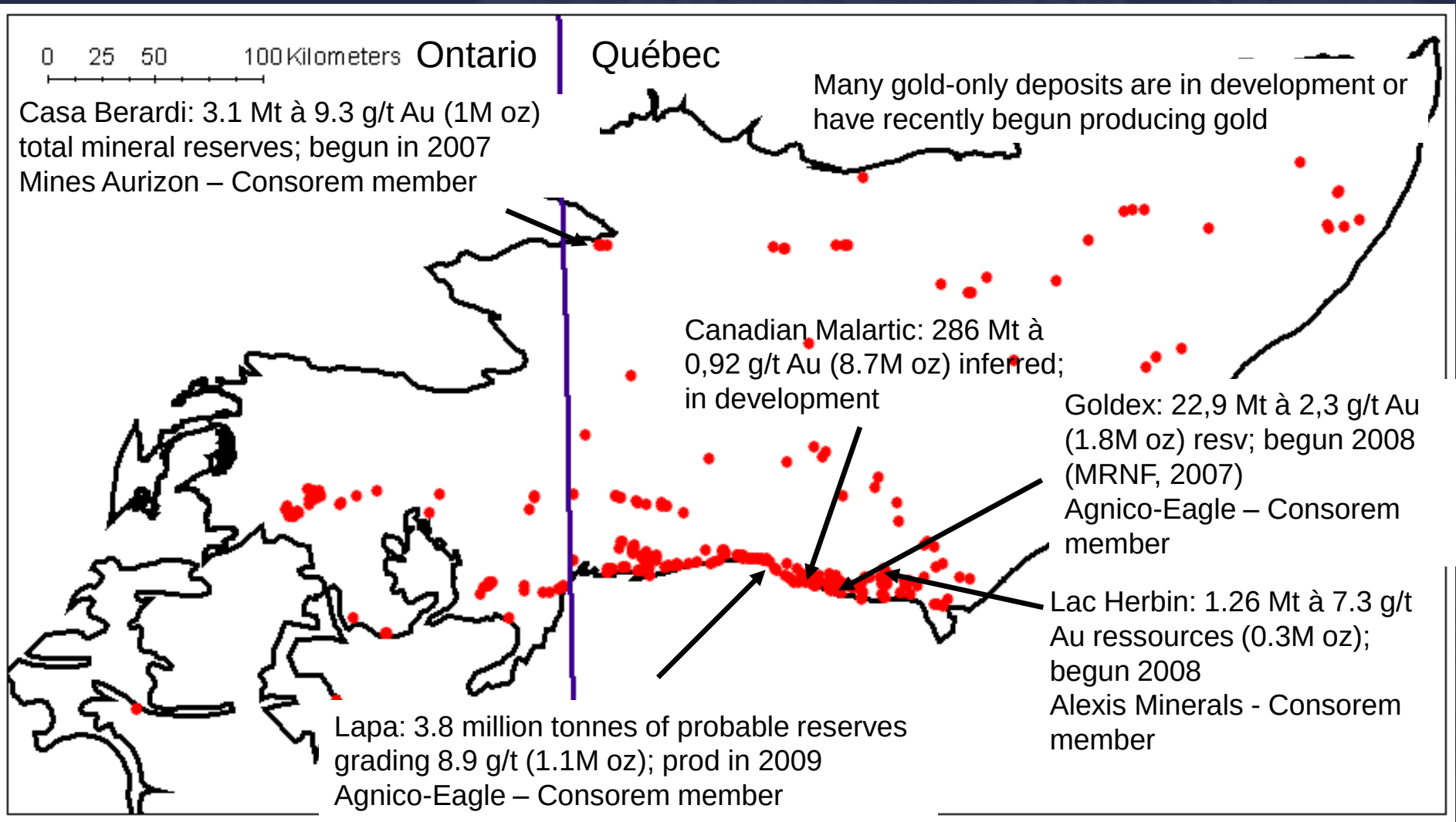


Golddeposits in the Abitibi subprovince: past and present

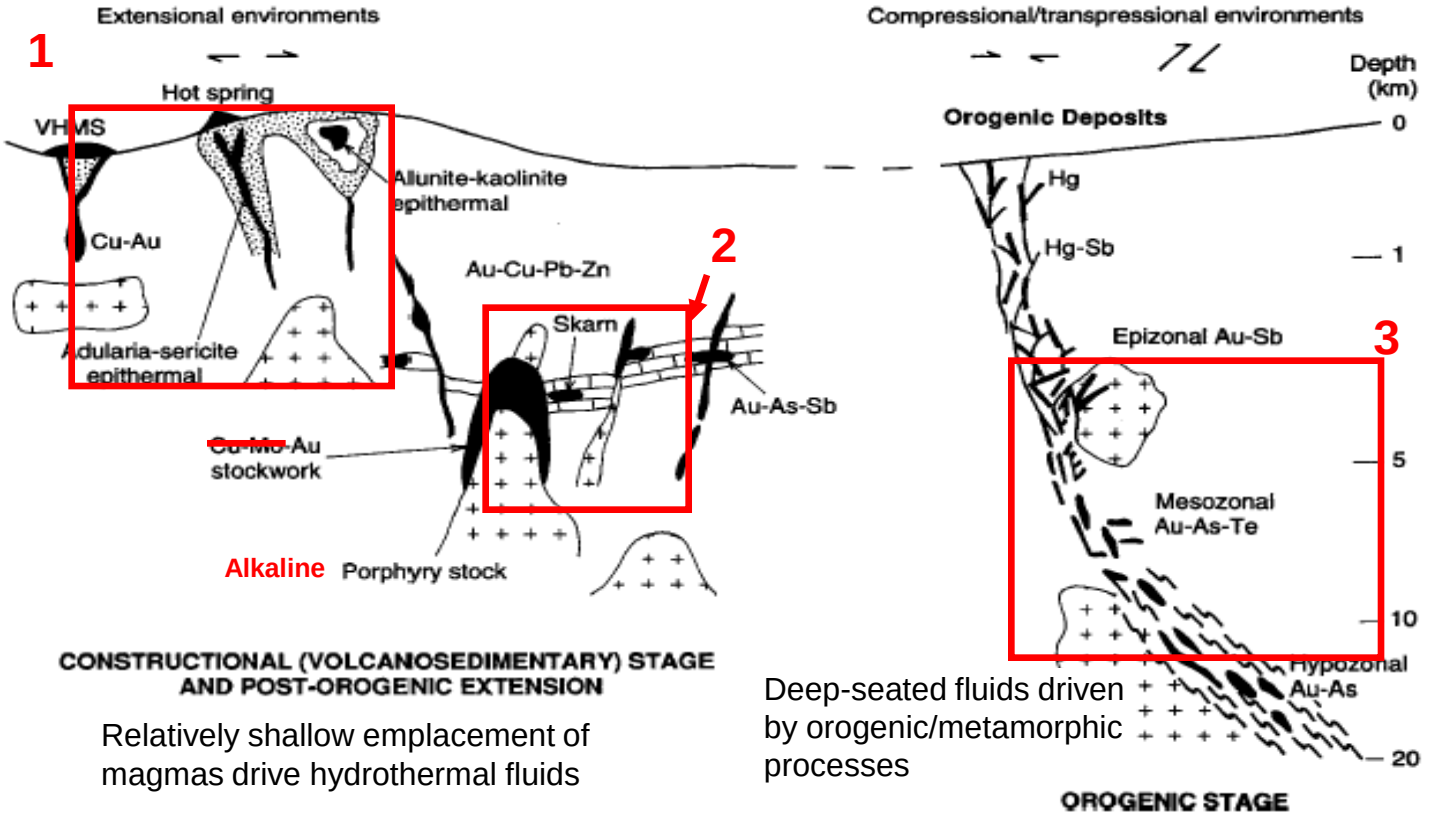
~ 5600 tons (190 M oz) gold; historical production + reserves from gold-only deposits (2005)
- Gold-only: no other substance typically recovered; excludes gold-rich VMS (ex: Horne, La Ronde) and Cu-Au veins (ex: Chibougamau)



Gold-only deposits in the Abitibi subprovince: still alive and well!



Abitibi subprovince gold-only deposits



From Groves, 1998

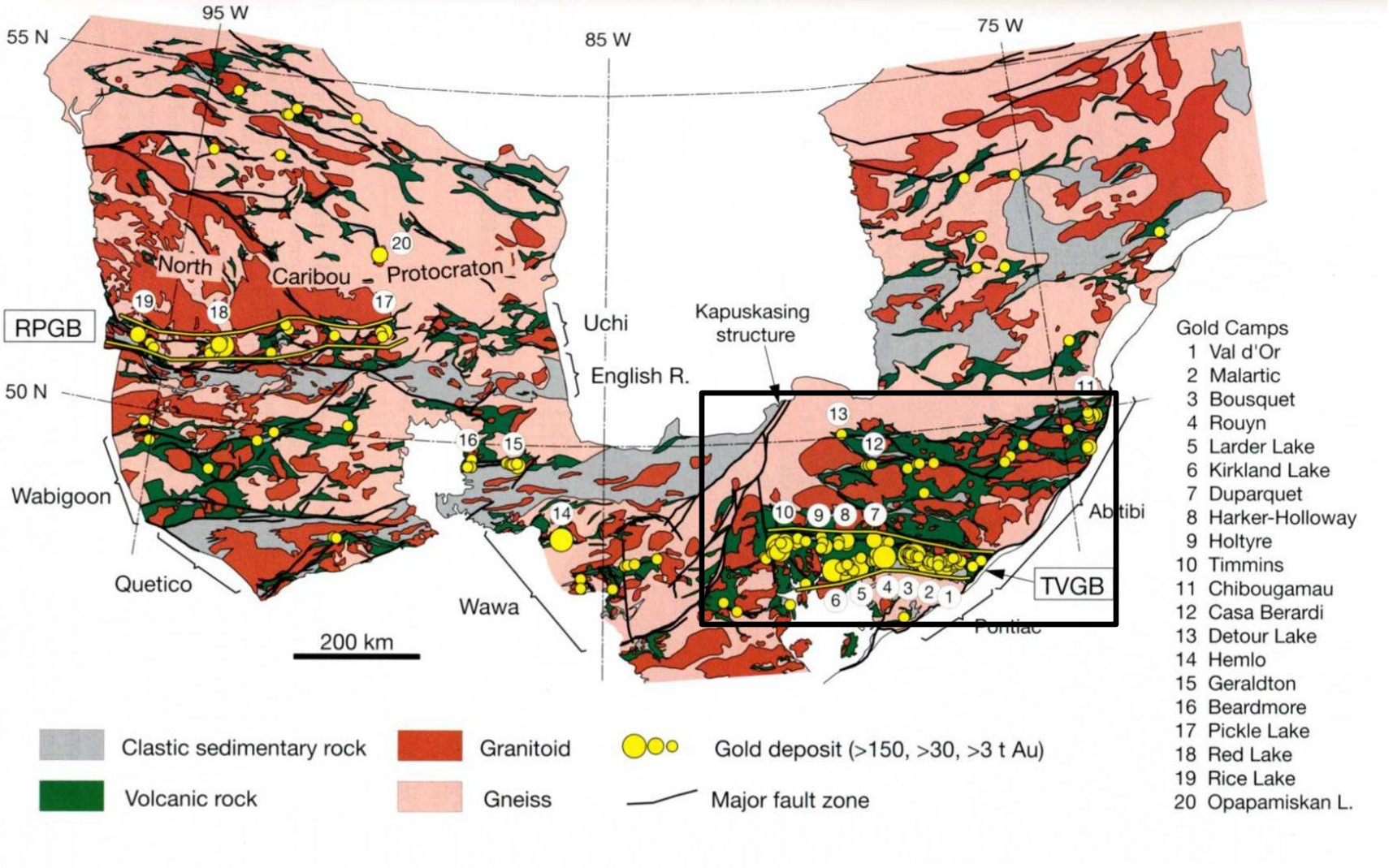
1. Gold-rich volcanogenic veins/replacement deposits within 2730–2695 Ma volcanic sequences (ex: some Bousquet camp deposits, Géant Dormant deposit)

2. Disseminated gold-bearing sulfide replacement zones associated with 2685-2670 Ma syenite-monzonite porphyry intrusions (Robert, 2001) → « syenite-associated »

3. Gold-bearing quartz-carbonate veins associated with regional deformations (~2690 Ma and ~2670 Ma probably) → « orogenic gold »

Gold mineralization and deformation zones, Superior Province

Main gold-only deposits in greenstone belts are associated with major, crustal-scale deformation zones (ex: Goldfarb et al, 2005, and many others)



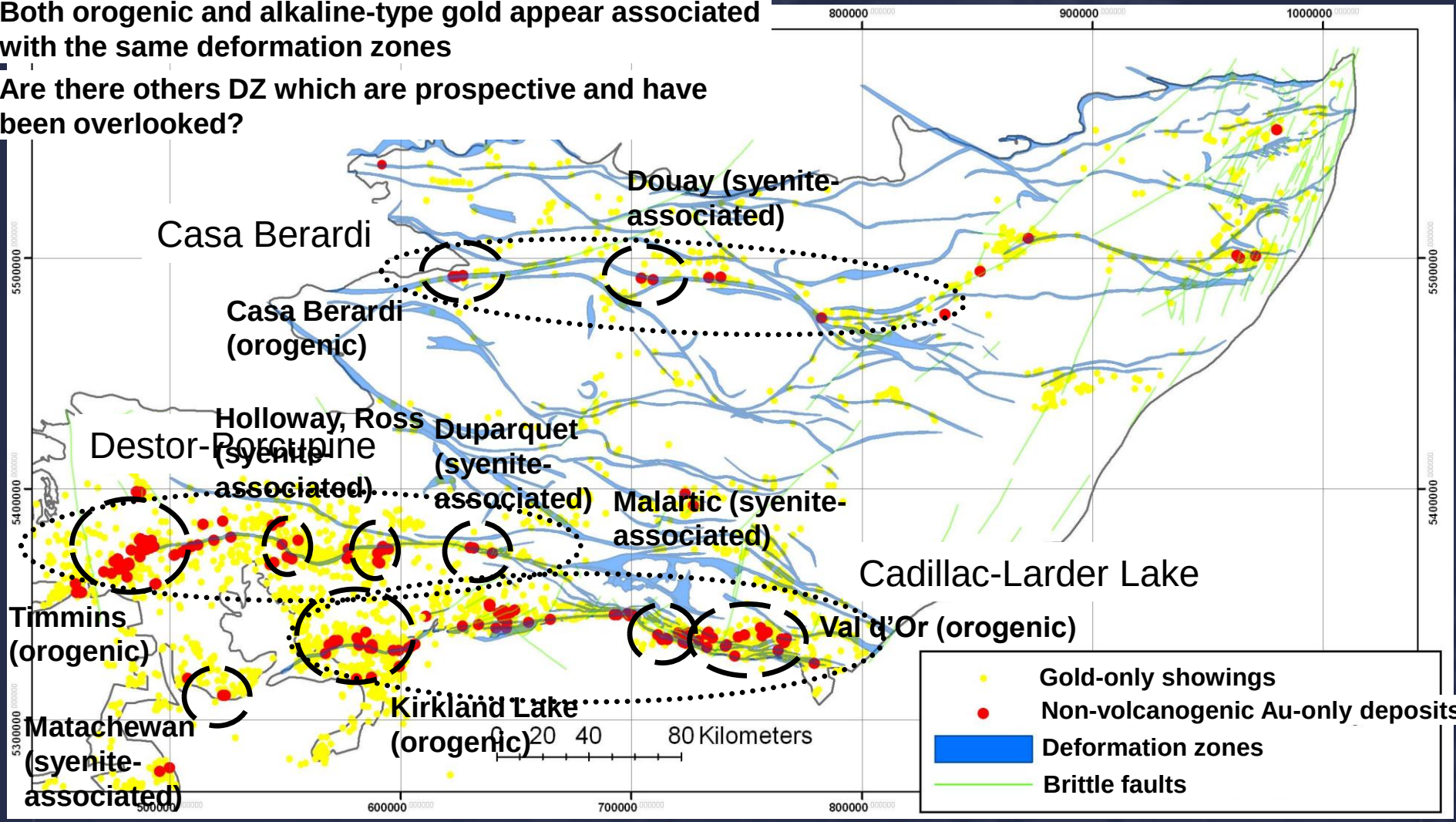
From Robert et al., 2005.

Most gold-only deposits in the AGB are associated with major deformation zones

3 main gold-bearing deformation zones.

Both orogenic and alkaline-type gold appear associated with the same deformation zones

Are there others DZ which are prospective and have been overlooked?



Référence deformation zones and brittle faults : Réal Daigneault, MB-96-33

Deposits + Mines: deposits or mines recognized as non-volcanogenic, with gold as the main economic substance, without significant copper and zinc and with more than 5 tons of gold produced or in reserves.

Showings : with Au as the main economic substance, without significant Cu or Zn.

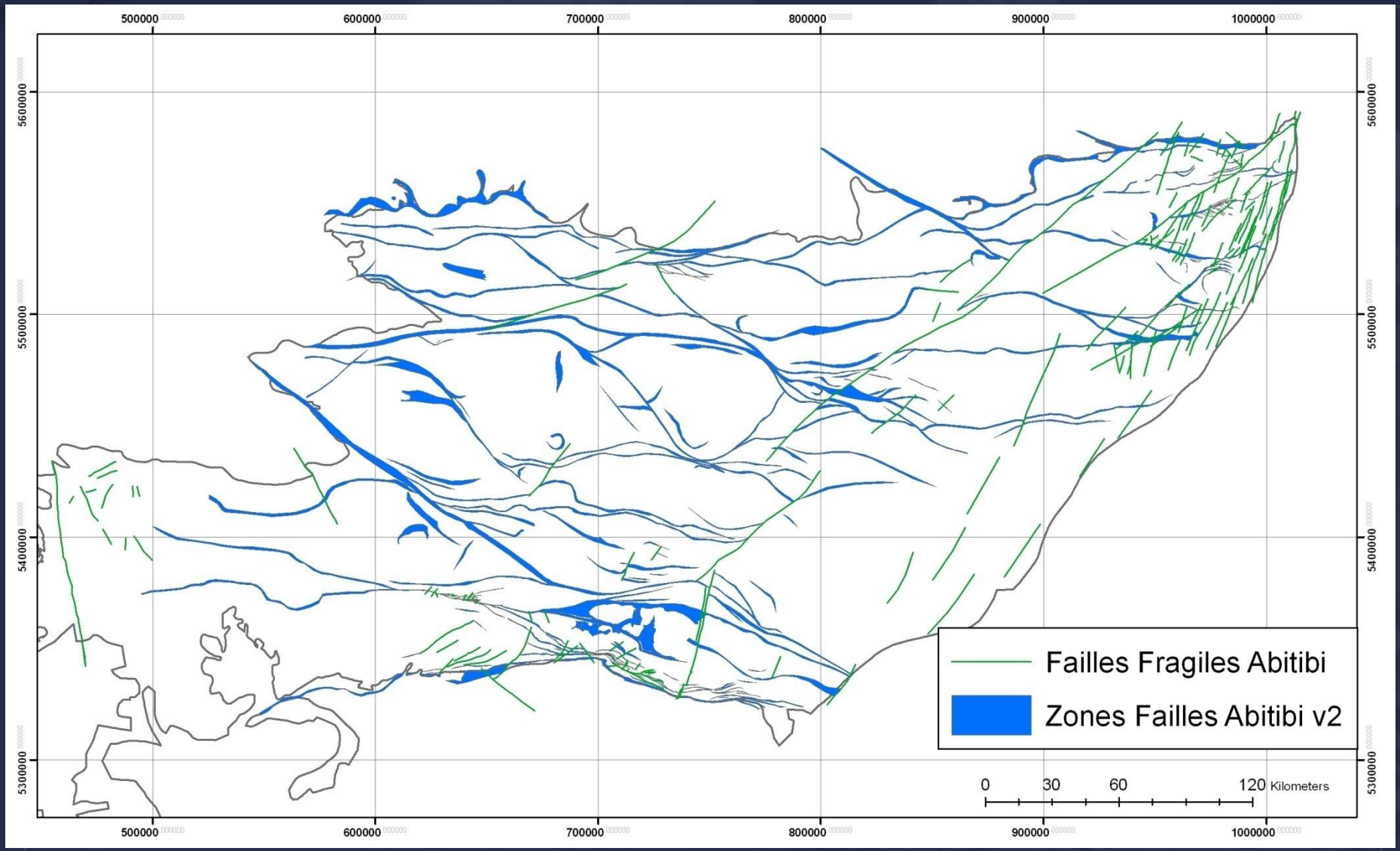
Project objectives

- Are there any other deformation zones that are gold-prospective and have been overlooked?
- Quantity the gold content of deformation zones for orogenic or syenite-associated gold
- Identify the lithogeochemical and lithological characteristics of known gold-bearing deformation zones
- Identify other deformation zones which have the same signature
- Take advantage of new geological compilation maps (Quebec and Ontario), new mineral deposit maps and models and lithogeochemical data from CONSOREM industrial partners.

Presentation outline

- **Selection and subdivision (segmentation) of deformation zones**
- **Calculation of the gold content of deformation zones segments**
- **Gold-prospectivity indicators and statistical association with the gold content of segments**
  - **Deformation zone classification**
  - **Association of various lithologies with the segments**
  - **Regional alteration around**
- **Consequences for regional exploration**

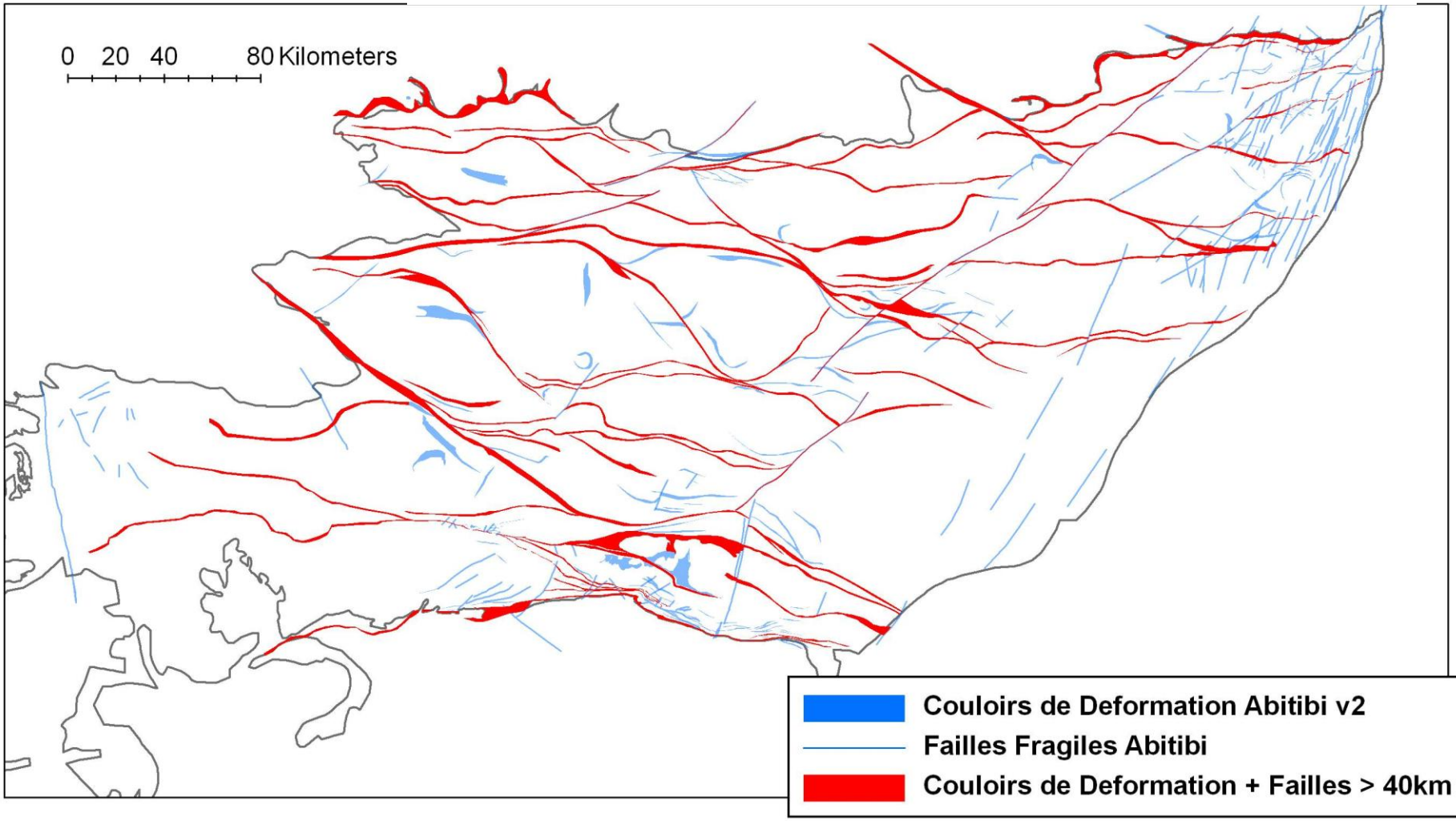
Abitibi deformation zones v.2



Référence DZ and brittle faults : Réal Daigneault, MB-96-33

Filtering of deformation zones that are less than 40 km in length; filtering of Proterozoic faults

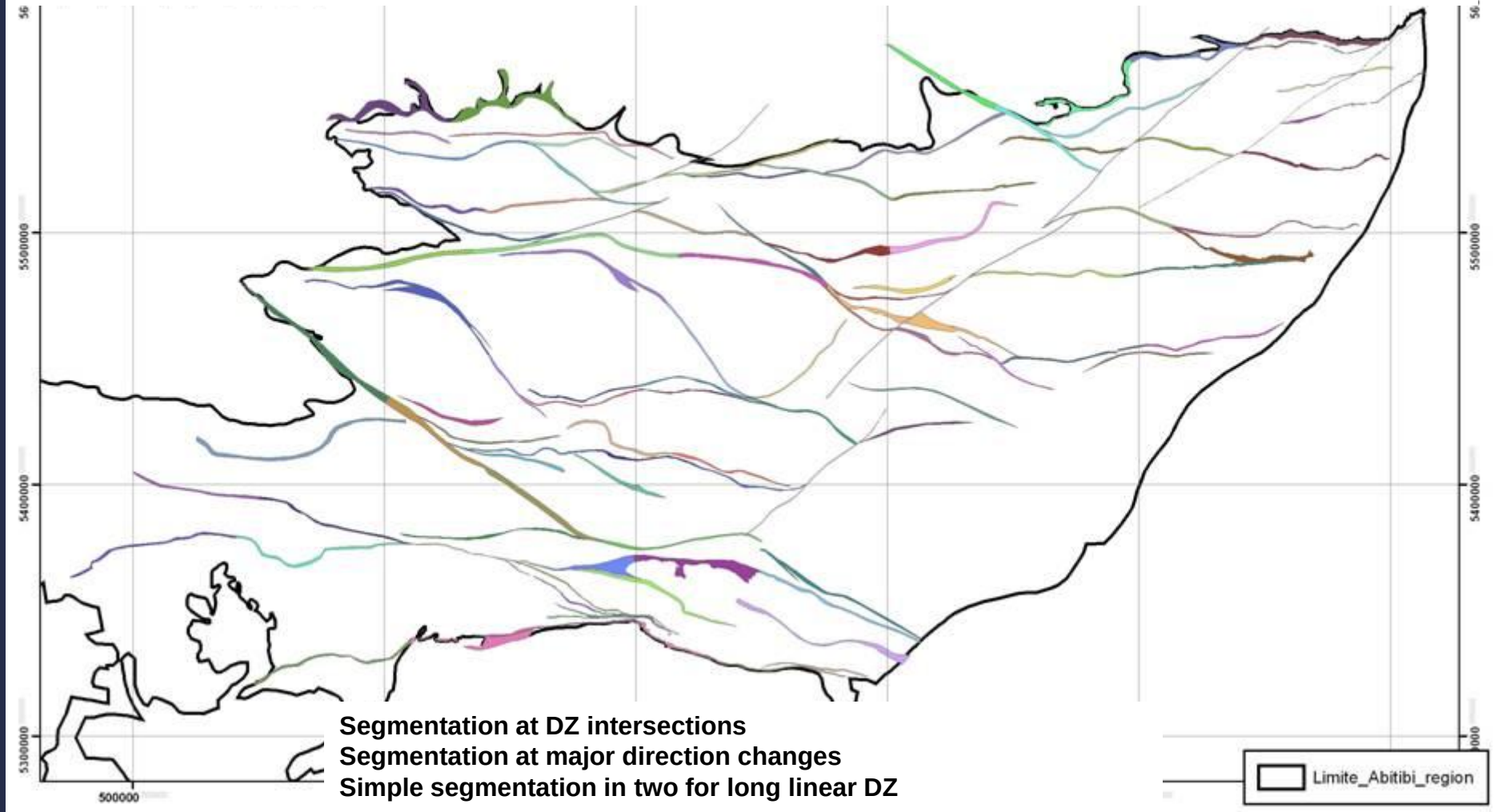
57 couloirs et failles fragiles retenues (en rouge)



Shorter DZ are less likely to be of crustal scale
Proterozoic faults are post-mineralization

Deformation zones subdivisions

Some deformation zones are very long (up to 260 km). The structural style, alteration and associated lithologies can vary along strike →
These longer segments have been subdivided in 40-80 km long segments → 108 segments



Segmentation at DZ intersections
Segmentation at major direction changes
Simple segmentation in two for long linear DZ

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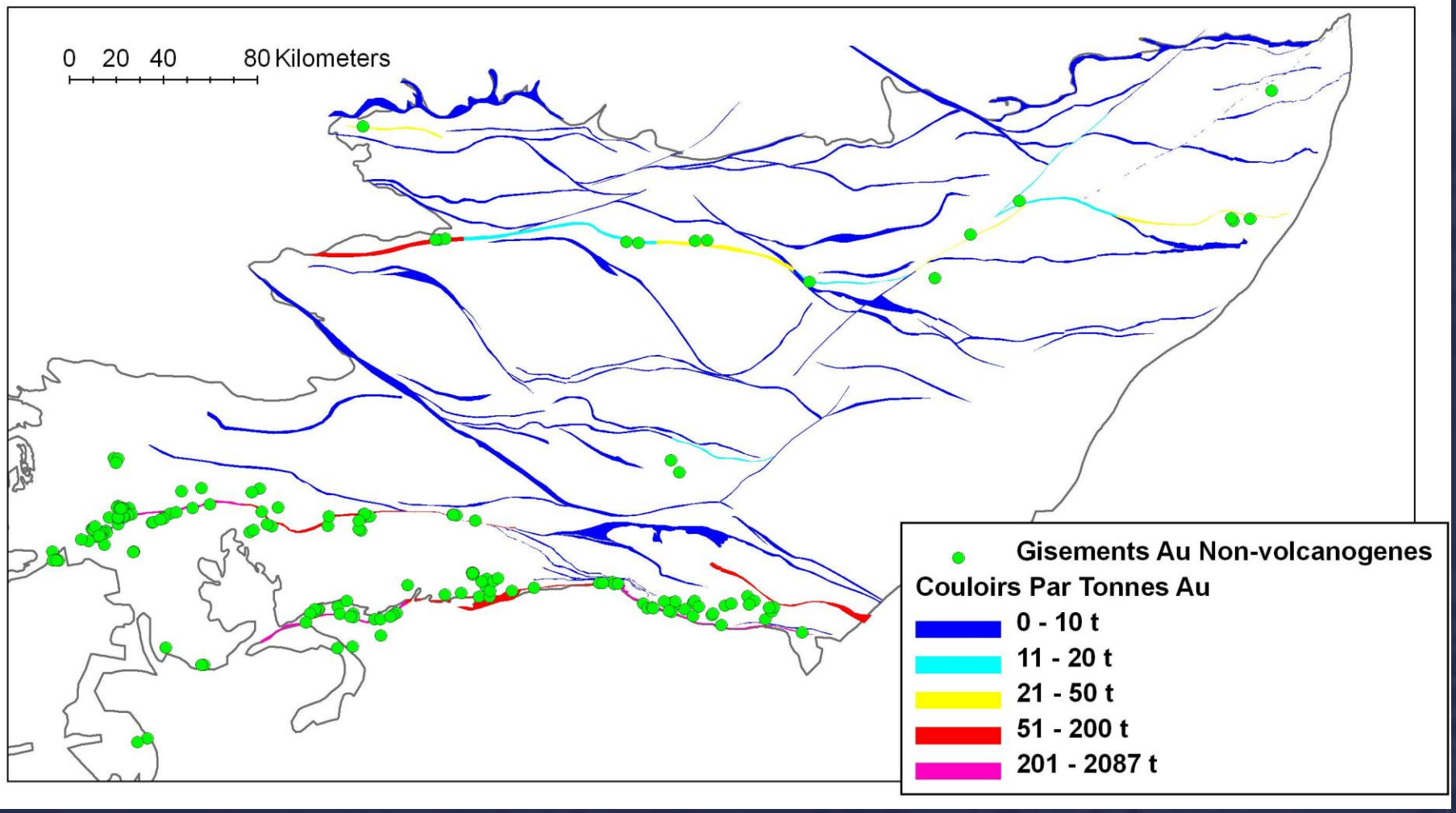
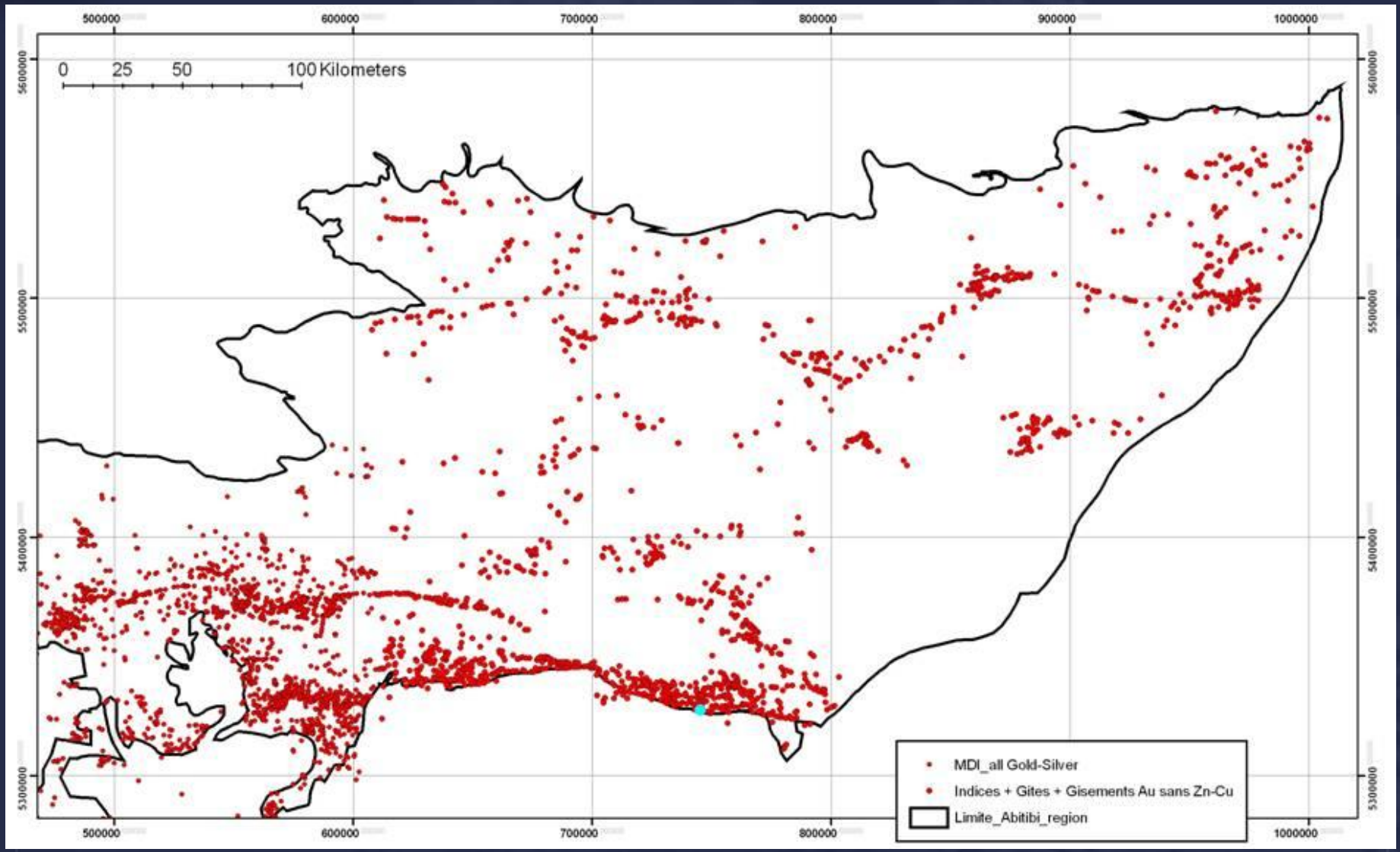
Gold content of DZ segments: 1) number of tons of gold produced + in reserves from gold-only, non-volcanogenic gold deposits



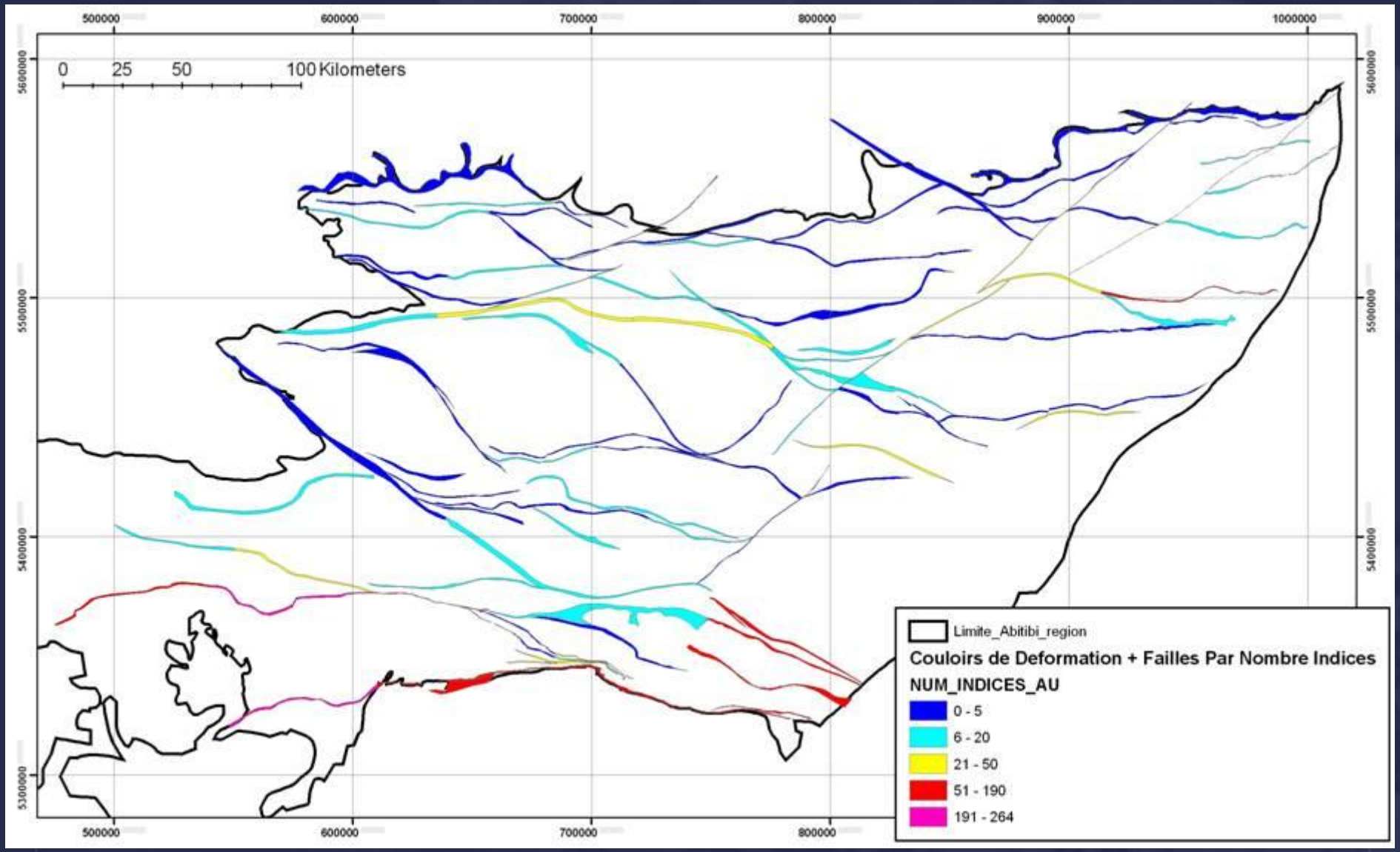
Every gold-only deposit has been assigned to the nearest DZ segment, if it is less than 10km from this segment.

Gold content of DZ segments 2) Number of gold-only showings by DZ segment



Showings, prospects and deposits with Au without significant Cu ou Zn. Each showing has been assigned to the nearest DZ segment if it is less than 5km from that segment (SIGÉOM ET MDI)

Gold content of segments: number of showings



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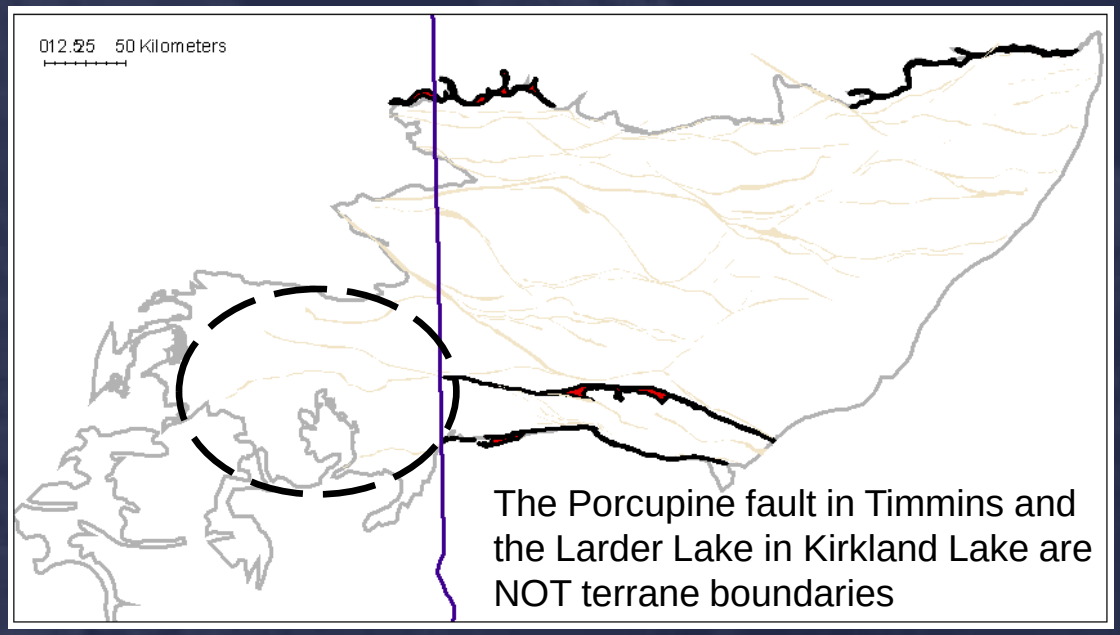
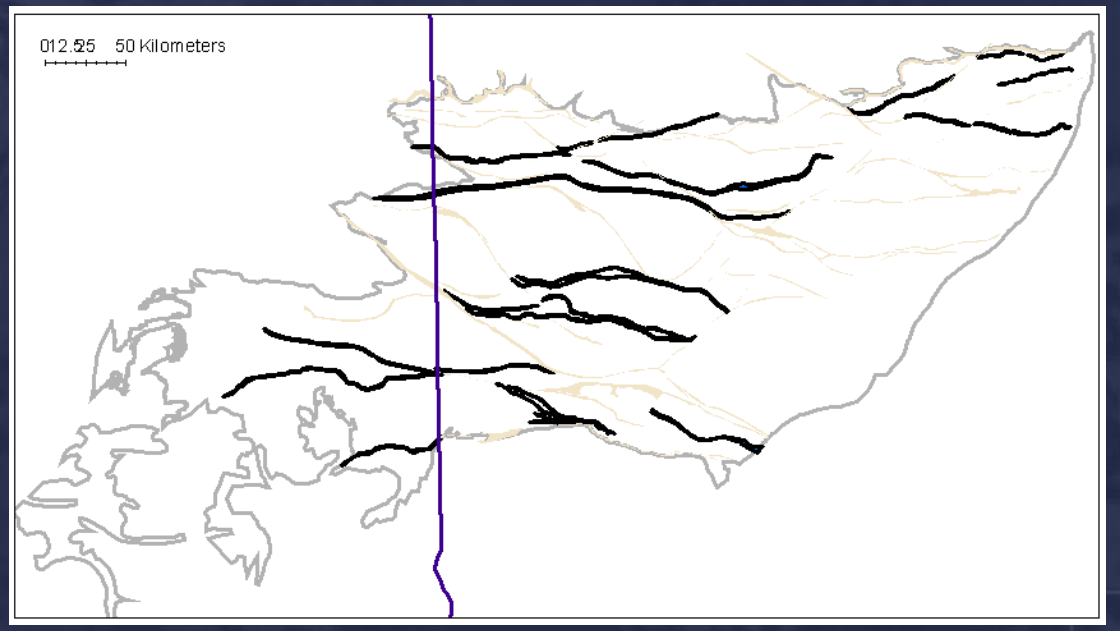
Classification of Abitibi DZ

Class 1: DZ representing terrane boundaries;
parallel to the stratigraphy;
complex kinematics
E-W orientated mainly



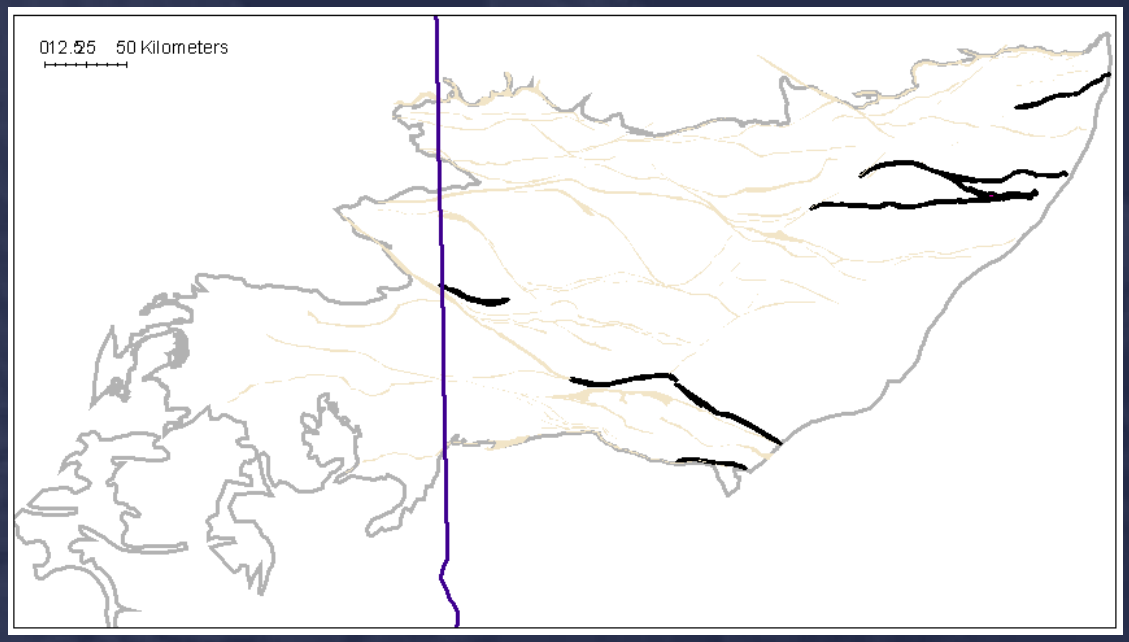
The Porcupine fault in Timmins and the Larder Lake in Kirkland Lake are NOT terrane boundaries

Class 2: DZ separating different stratigraphic units (ex: séd-volcanics);
parallel to the stratigraphy;
mainly down-dip movement
E-W orientated mainly

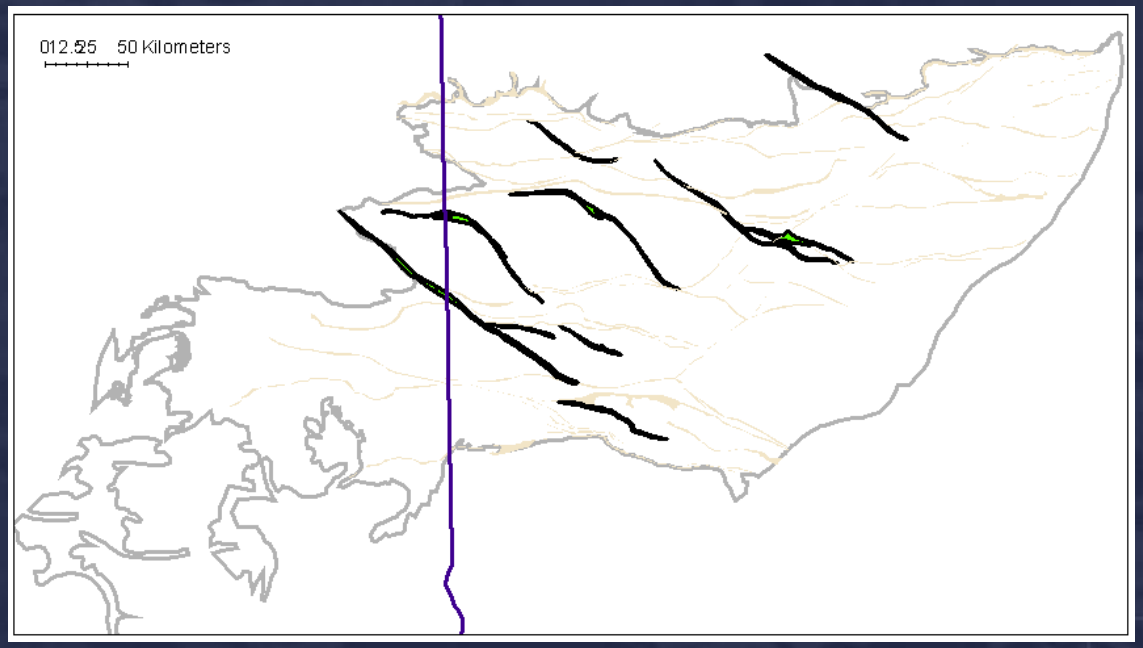


Classification of Abitibi DZ

Class 3: DZ within stratigraphic units;
parallel to the stratigraphy;
down-dip or oblique movement

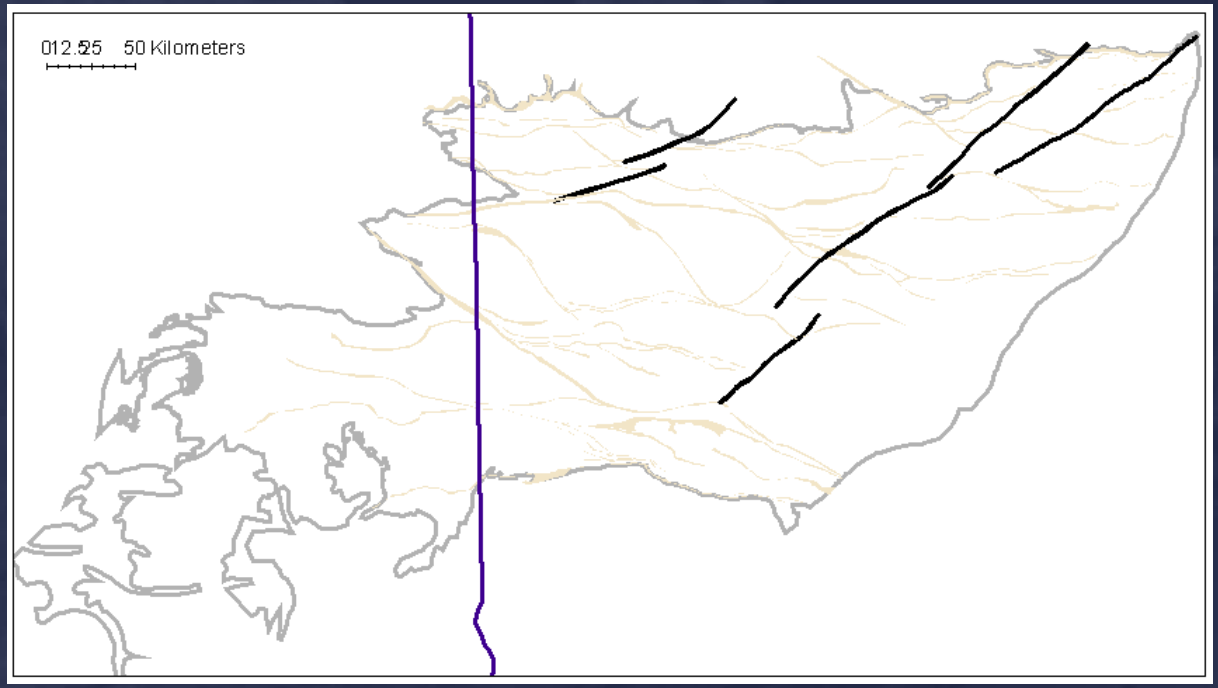


Class 4: DZ that cross-cut the regional stratigraphy
Main orientation SE-NW
Strike-slip kinematics

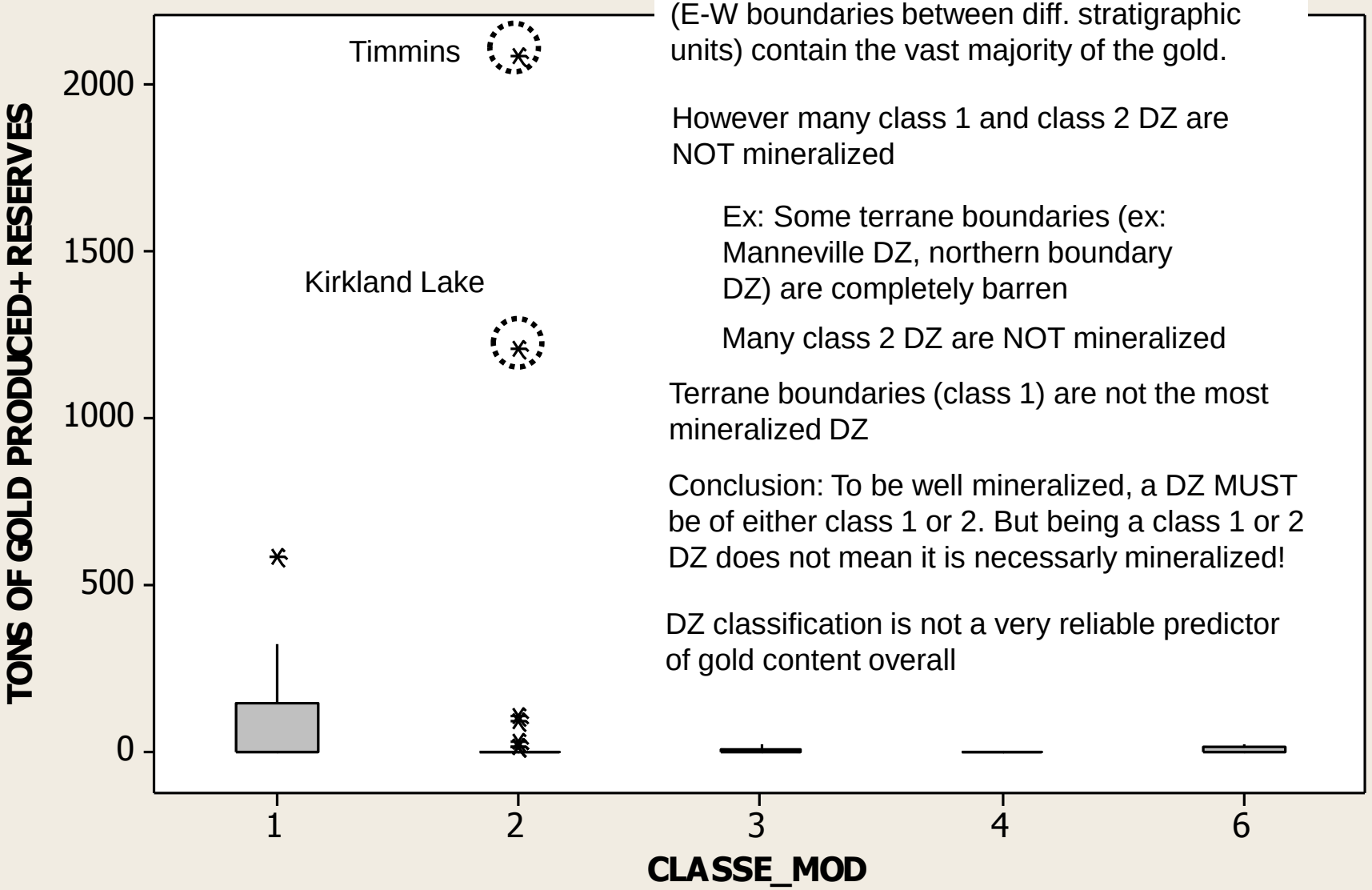


Classification of Abitibi DZ

Class 6: Brittle fault, cross-cutting the stratigraphy. NE-NNE orientations are dominant



DZ classification and gold content



Class 1 (E-W terrane boundaries) and class 2 (E-W boundaries between diff. stratigraphic units) contain the vast majority of the gold.

However many class 1 and class 2 DZ are NOT mineralized

Ex: Some terrane boundaries (ex: Manneville DZ, northern boundary DZ) are completely barren

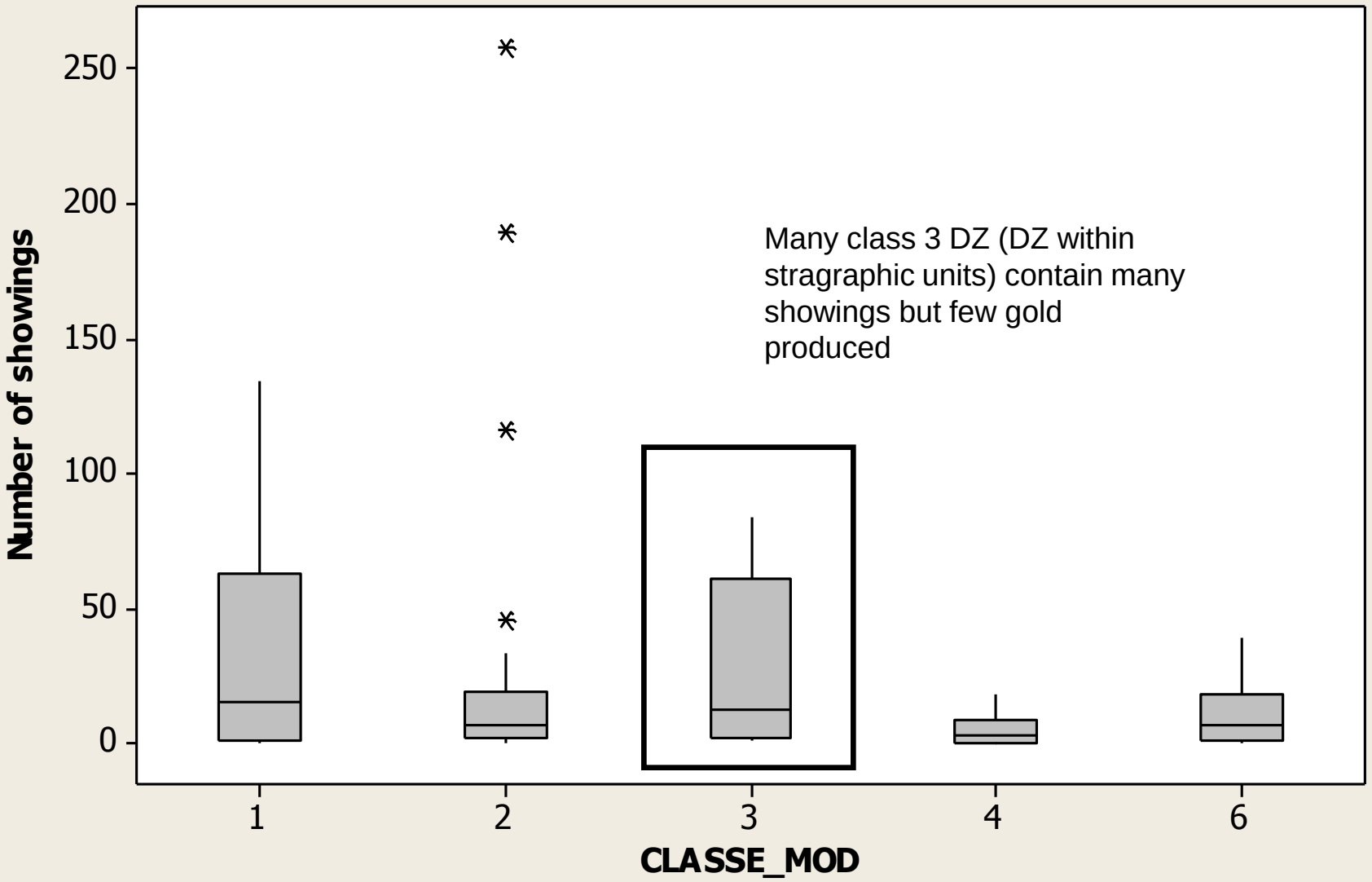
Many class 2 DZ are NOT mineralized

Terrane boundaries (class 1) are not the most mineralized DZ

Conclusion: To be well mineralized, a DZ MUST be of either class 1 or 2. But being a class 1 or 2 DZ does not mean it is necessarly mineralized!

DZ classification is not a very reliable predictor of gold content overall

DZ classification and number of showings



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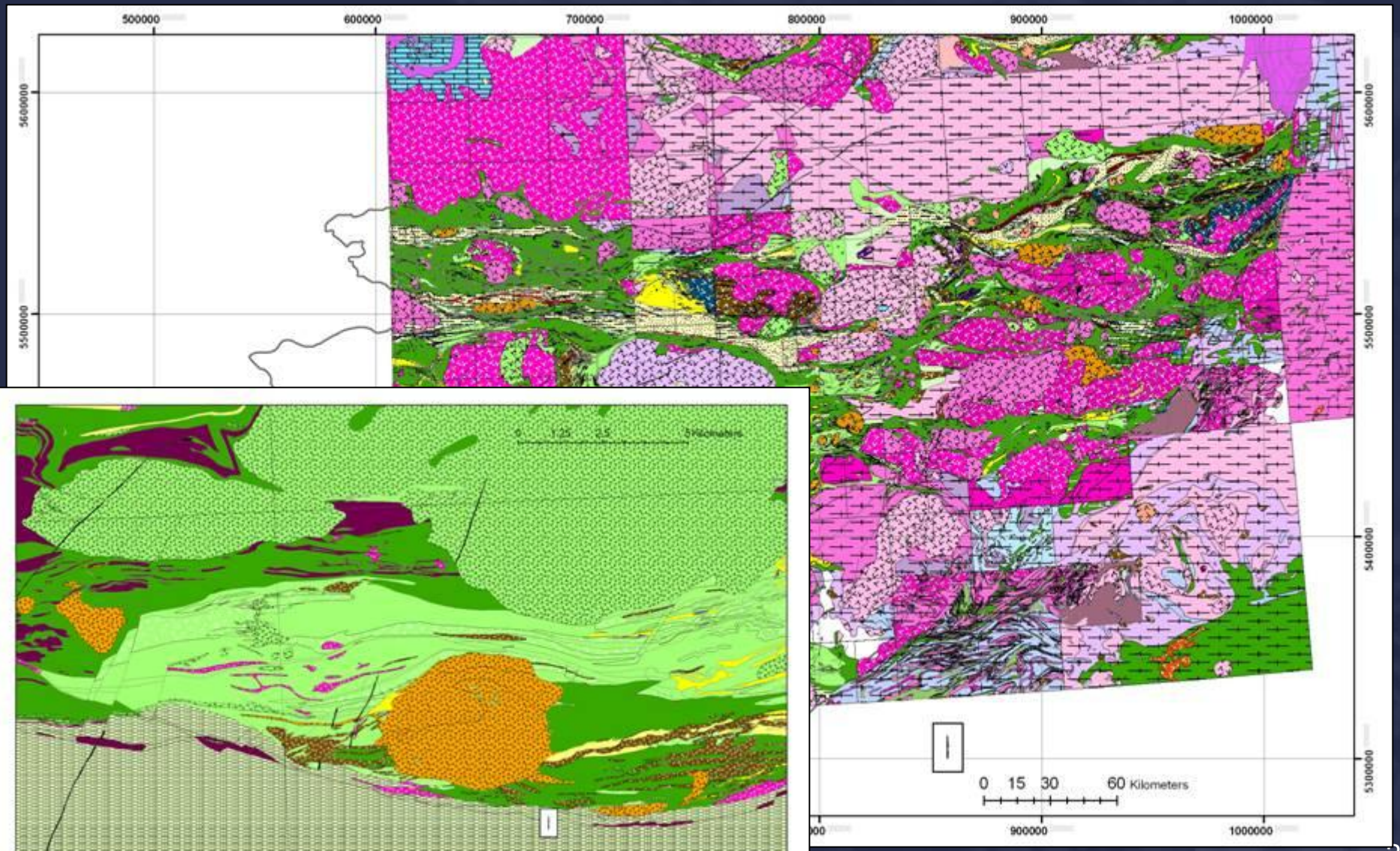
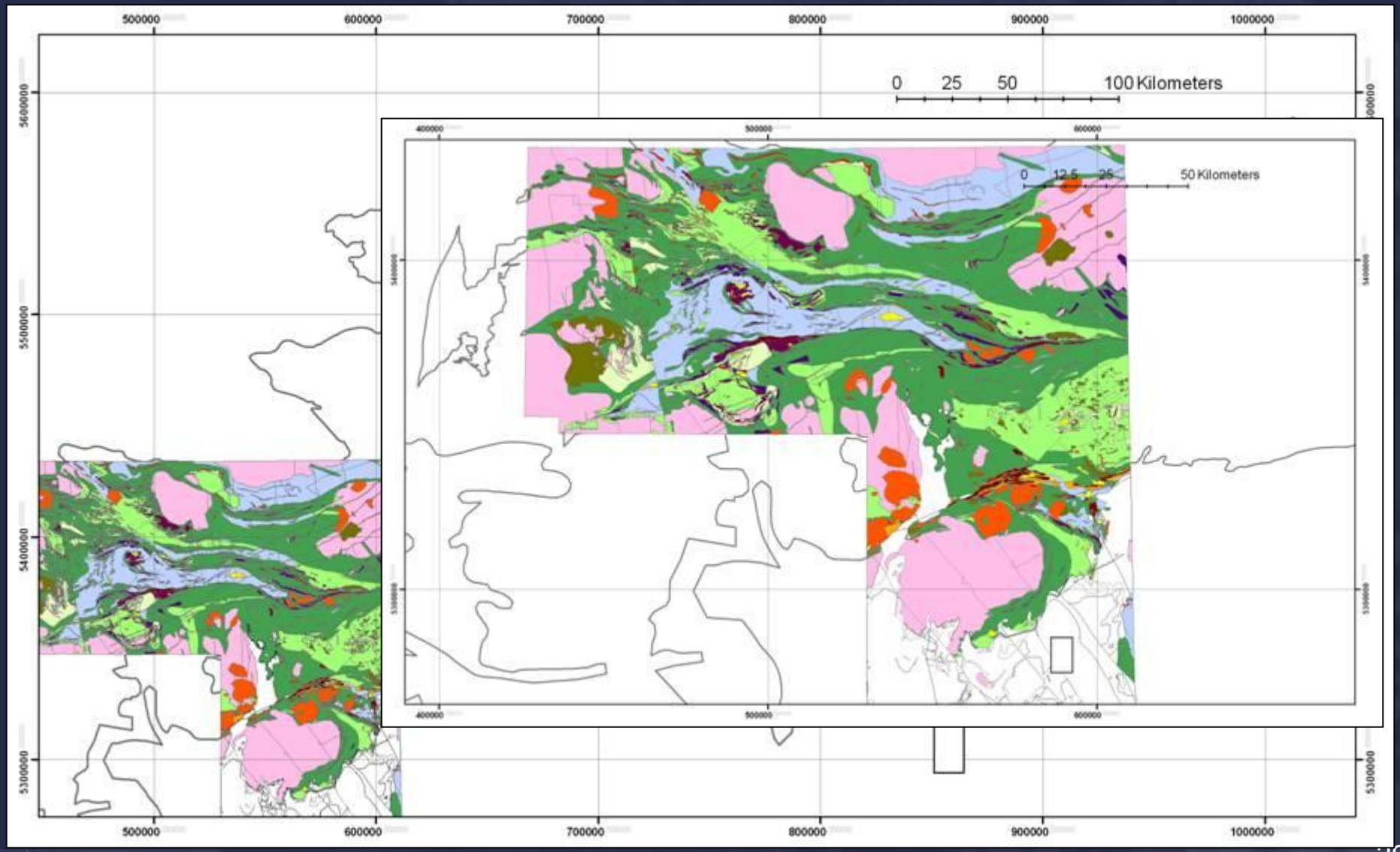
Base maps for lithological associations : EP-2006-01 (Lamothe, 2006)



Base maps for Lithological association : OGS MRD-186 (OGS, 2005)



Association between gold and various lithologies, Abitibi-Superior province

- Many lithologies have been previously proposed as being closely associated with orogenic/syenitic gold deposits in the Abitibi/Superior province. What can we say about these associations using the most current compilation maps?

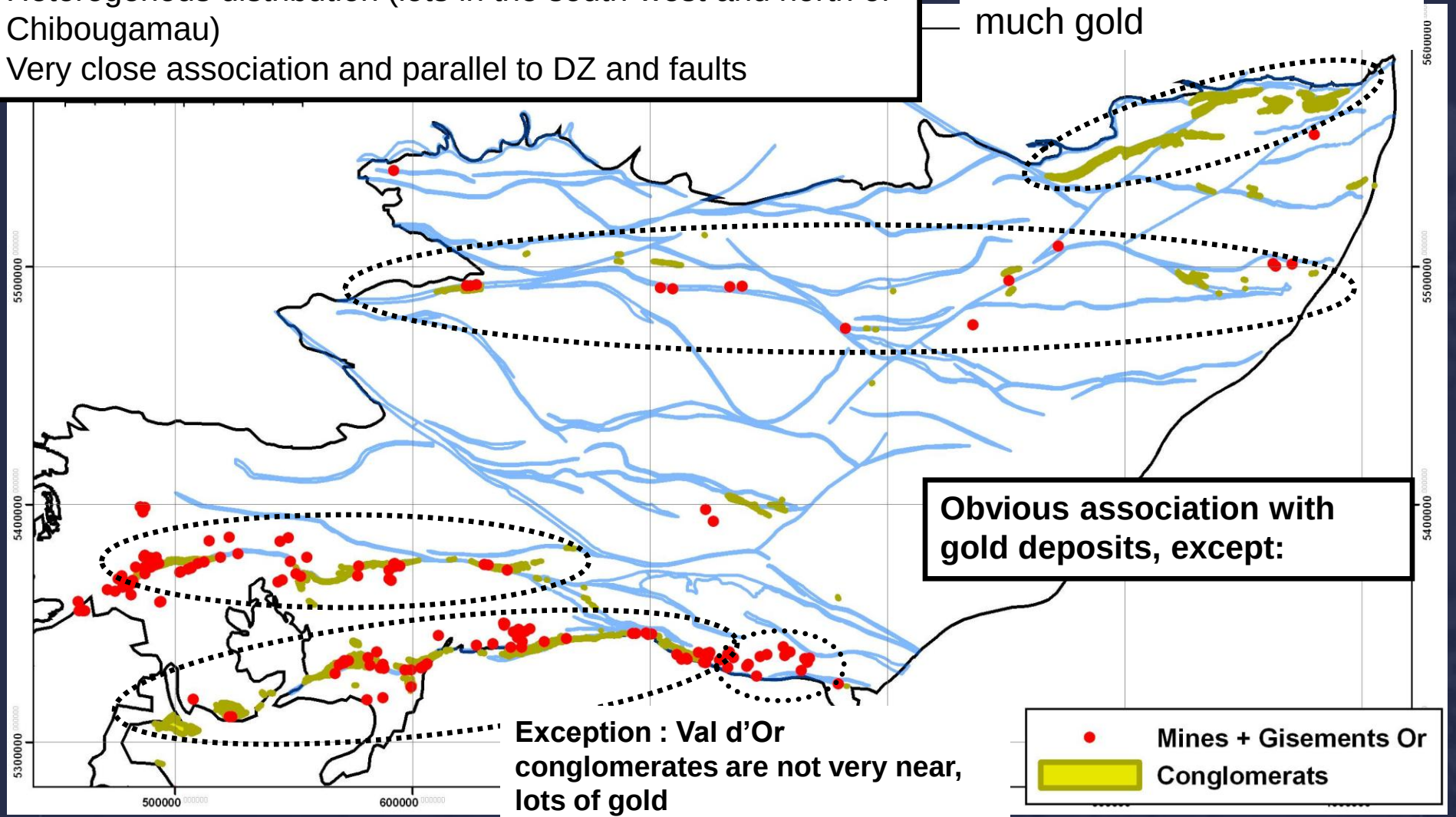
  - Felsic porphyry intrusions (ex: Hodgson, 1993; Robert et al., 2005, and others)
  - Conglomerates (ex: Poulsen, 2000)
  - Alkaline intrusions (syenites-monzonites) (ex: Robert, 2001)
  - Alkaline volcanic rocks
  - Ultramafic volcanic rocks (ex: Robert et al., 2005, et autres)
  - Ultramafic intrusive rocks

- Next slides: distribution of these lithologies in the Abitibi, spatial assocation with DZ (visually), and association between lithologies and gold deposits (visually)

Conglomerates, DZ segments et gold deposits

Heterogenous distribution (lots in the south-west and north of Chibougamau)
Very close association and parallel to DZ and faults

Lots of conglomerates, not much gold



Obvious association with gold deposits, except:

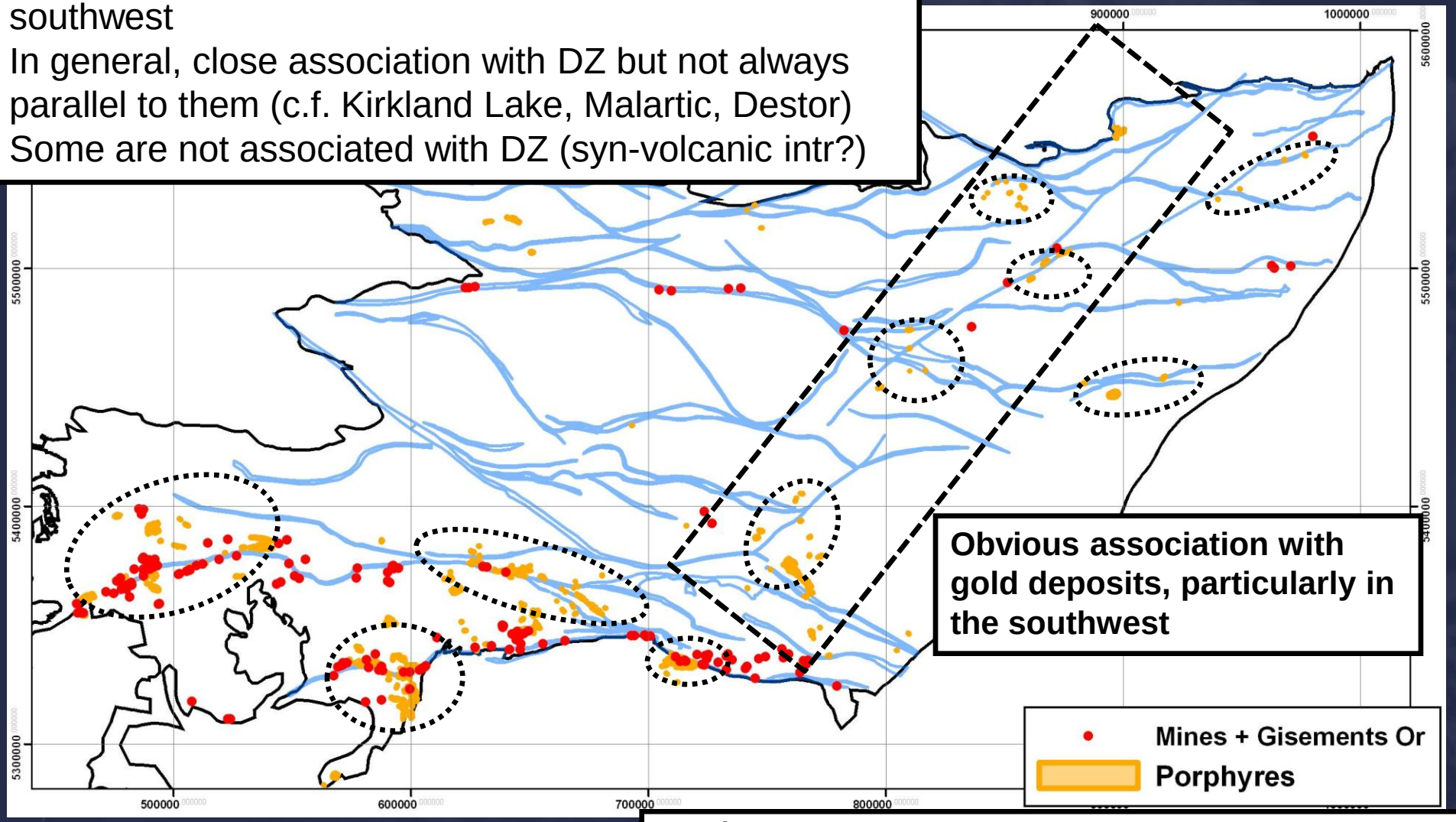
Exception : Val d'Or conglomerates are not very near, lots of gold

SIGÉOM : Lithologie = 'Conglomérat' (simplification, dominant lithology of the stratigraphic unit)
OGS : Rock_Type = 'Temiskaming-type Clastic Metasedimentary Rocks'

Association Au-Conglomérats: Hodgson, 1993; Robert, 2000; Gardoll, 2005

Felsic porphyry intrusions, DZ segments and gold deposits

Heterogenous distribution: a lot in the south and southwest
In general, close association with DZ but not always parallel to them (c.f. Kirkland Lake, Malartic, Destor)
Some are not associated with DZ (syn-volcanic intr?)



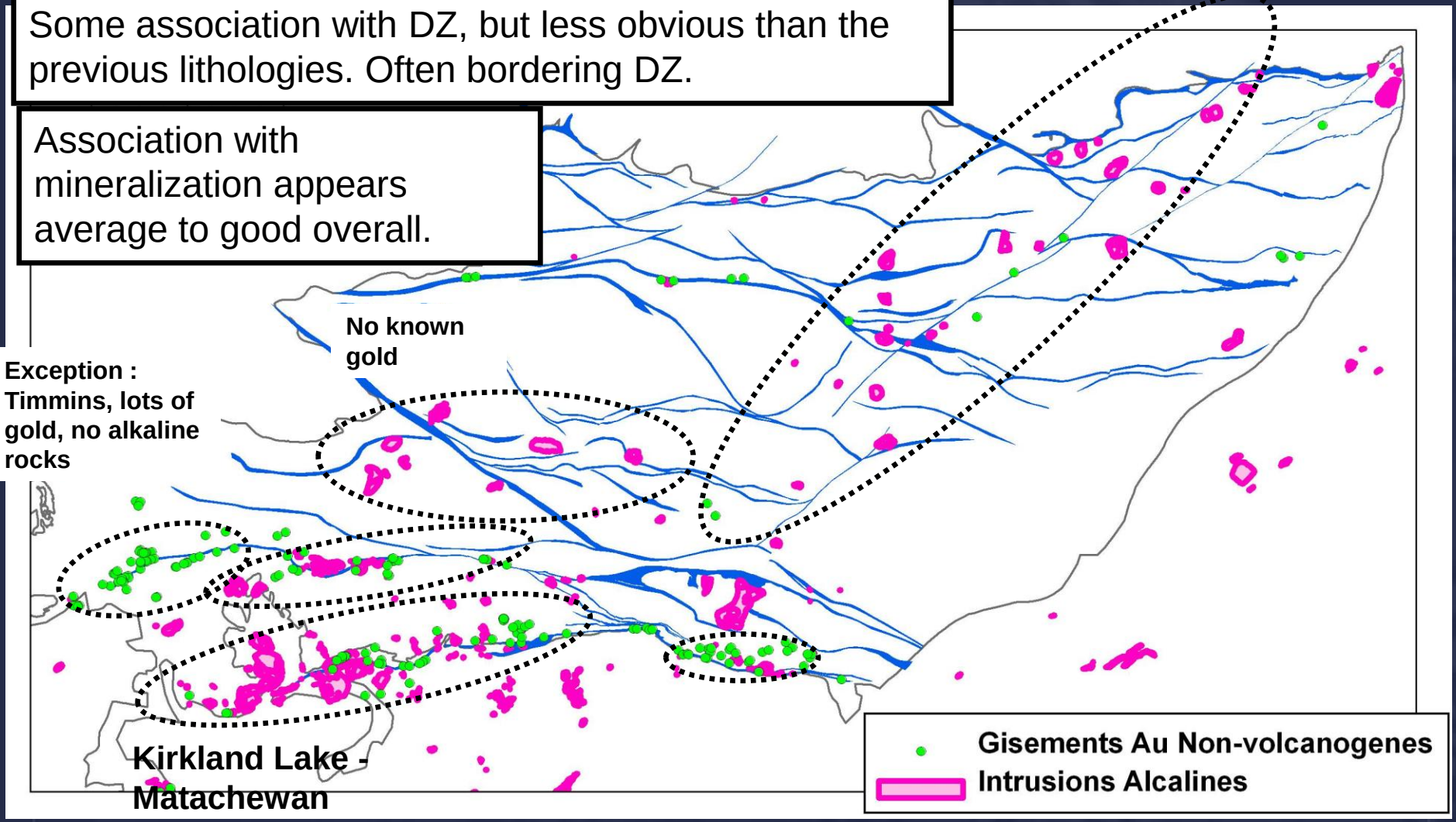
SIGÉOM : Lithologie = ‘Intrusion felsique porphyrique’
OGS : Rock_Type = ‘Porphyry suite'

Association Au-Porphyres felsiques: Gardoll, 2005

Alkaline intrusions (syenites, monzonites), DZ segments and gold deposits

Some association with DZ, but less obvious than the previous lithologies. Often bordering DZ.

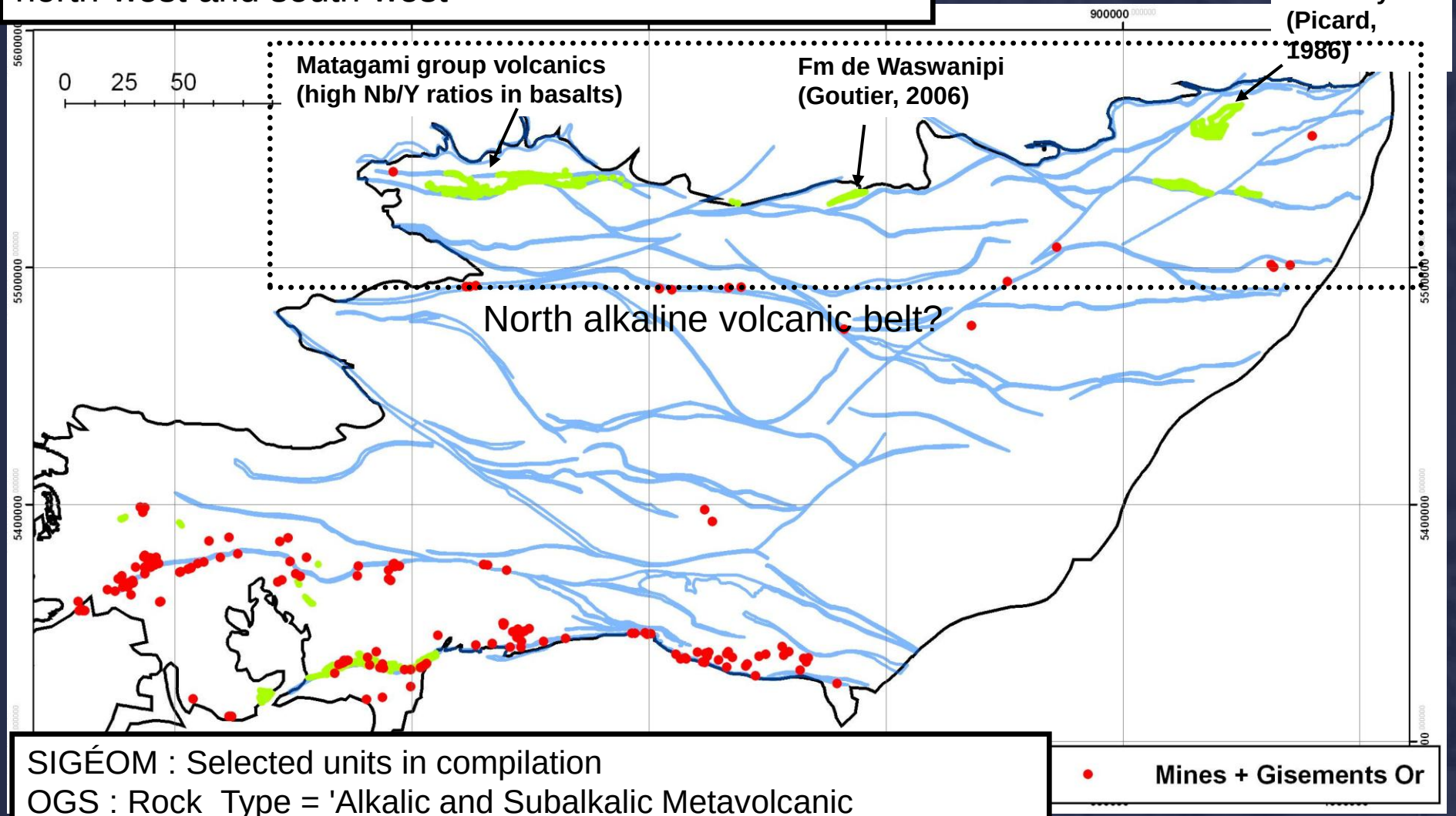
Association with mineralization appears average to good overall.



SIGÉOM : Lithologie = ‘Syenite’ OR ‘Monzonite’ → (Robert, 2001)
OGS : Rock_Type = ‘Alkalic intrusive suite'

Alkaline volcanic rocks and DZ segments

Found in the extreme corners of the Abitibi: north-east-north-west and south-west

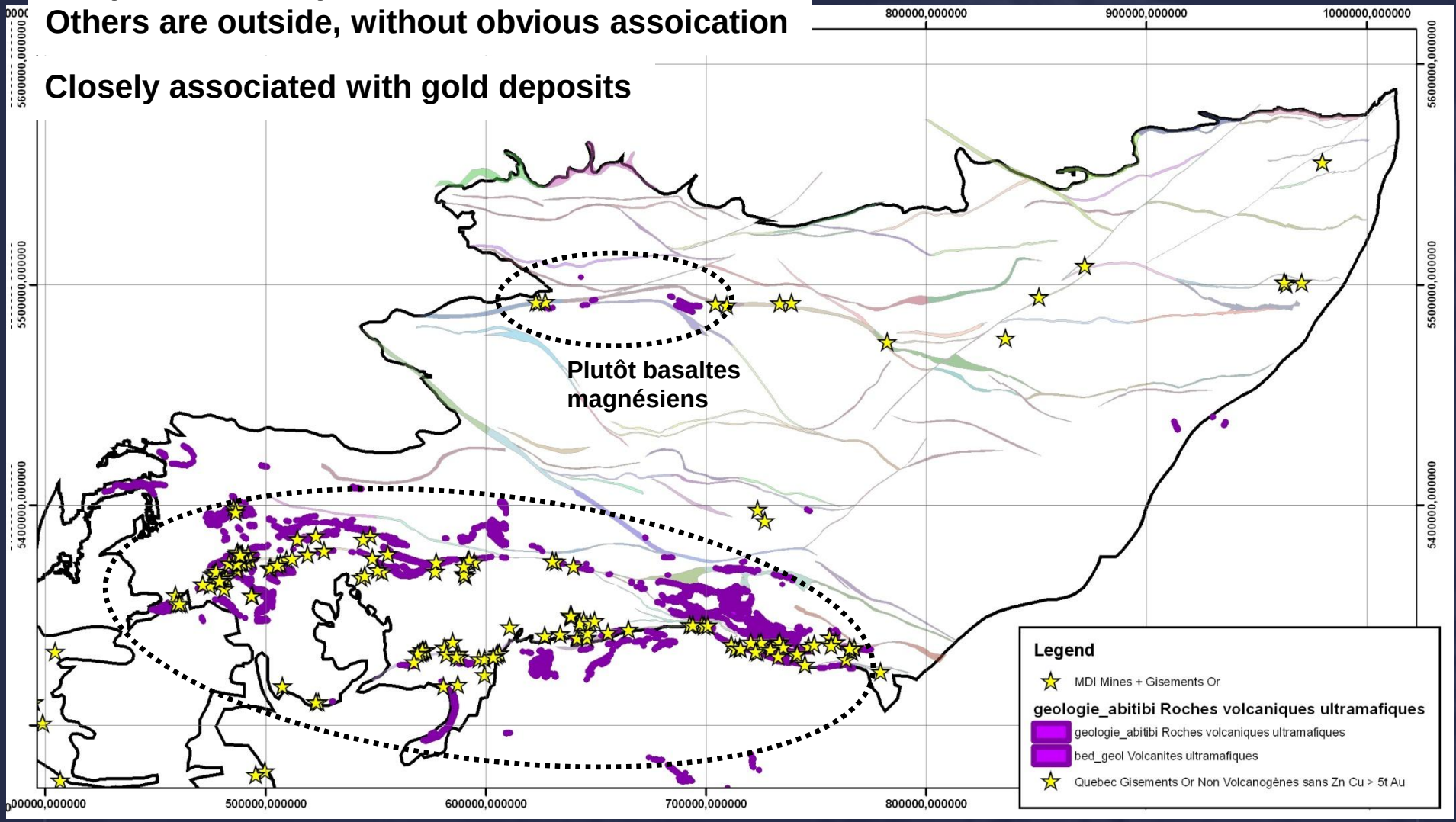


SIGÉOM : Selected units in compilation
OGS : Rock_Type = 'Alkalic and Subalkalic Metavolcanic Rocks/Intrusions (Unconformable Timiskaming-type)"

Ultramafic volcanics, DZ segments and gold deposits

Many units closely follow deformation zones
Others are outside, without obvious assoication

Closely associated with gold deposits



SIGEOM: "Lithologie" ='Volcanite ultramafique'

OGS: "ROCK_TYPE"= 'Ultramafic to Mafic Metavolcanic Rocks/Intrusions'

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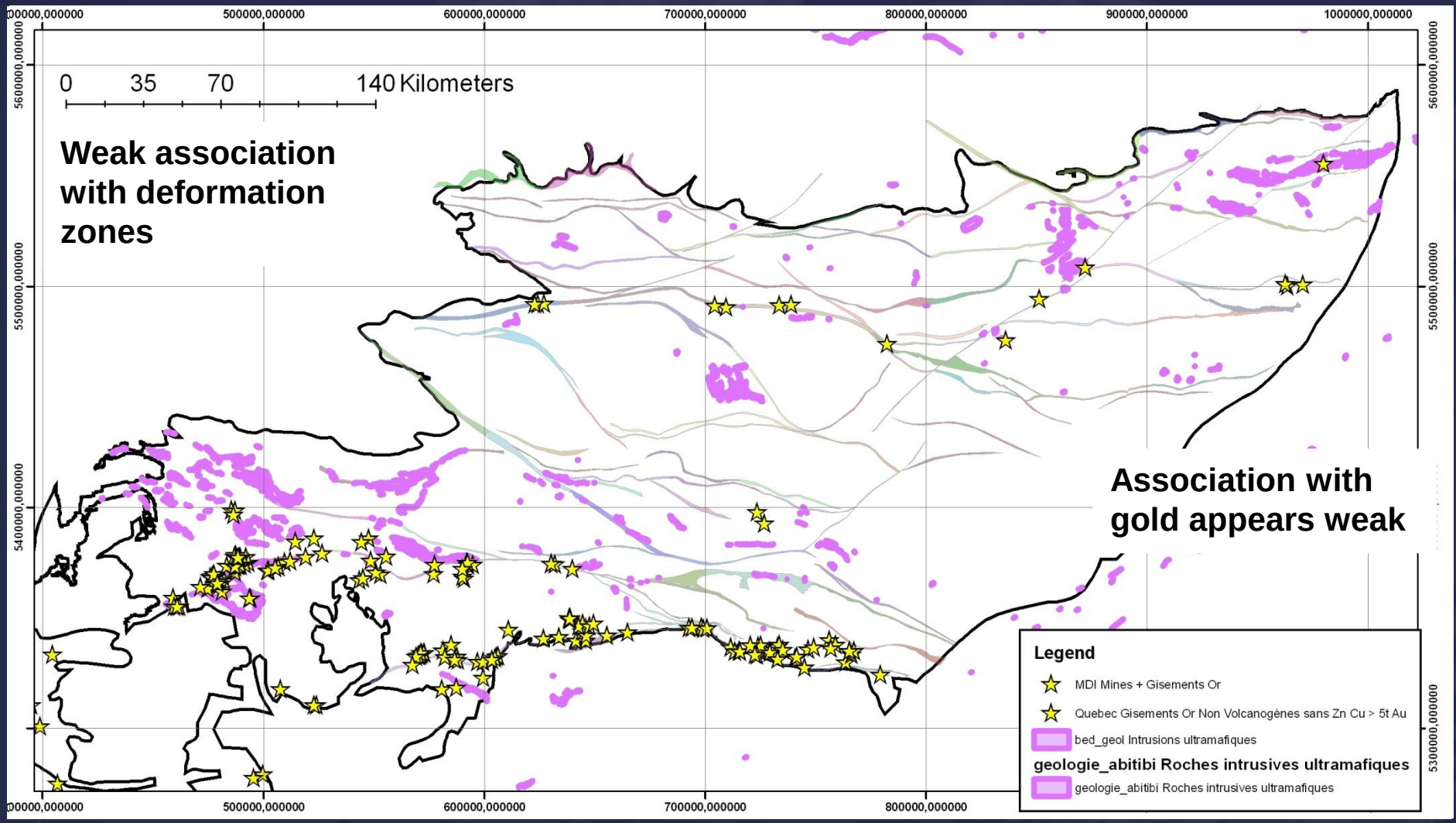
Ultramafic intrusions, DZ segments and gold deposits



SIGEOM: "Lithologie"= 'Roche intrusive ultramafique' OR "Lithologie" = 'Péridotite' OR "Lithologie" = 'Pyroxénite'

OGS: "ROCK_TYPE"= 'Ultramafic Intrusive Rocks'

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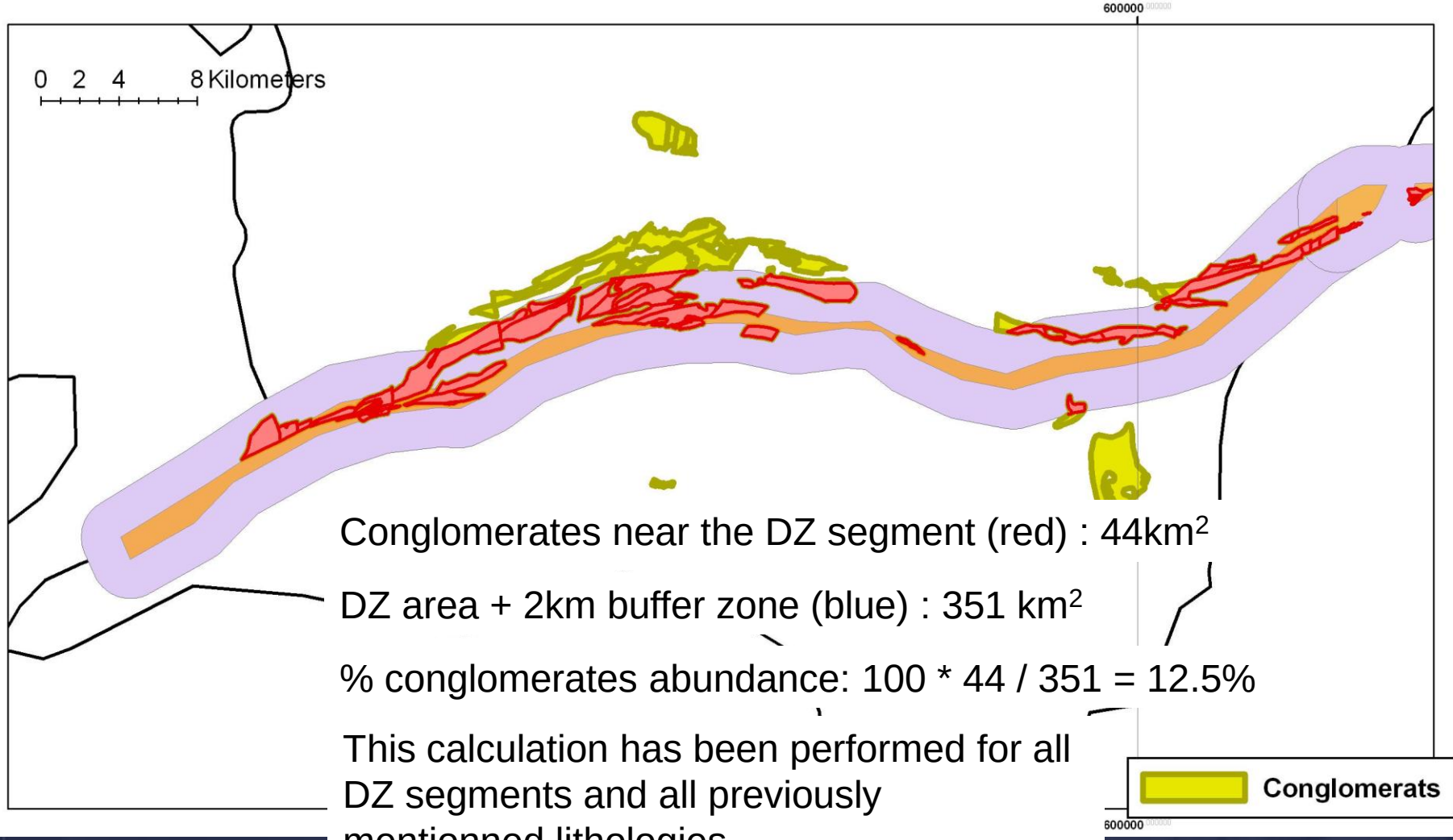
Association between lithologies and deformation zones segments



Conglomerates near the DZ segment (red) : 44km^2

DZ area + 2km buffer zone (blue) : 351 km^2

% conglomerates abundance: 100 * 44 / 351 = 12.5%

This calculation has been performed for all DZ segments and all previously mentionned lithologies

Association between the gold content of DZ segments and lithological abundances of segments

Pearson correlation coefficient between log (% abundance) of various lithologies and ln(tons Au) et ln (number of showings)

	Tons gold	Number of gold showings
Ultramafic volcanics	**0.47**	**0.50**
Conglomerates	**0.43**	**0.28**
Felsic porphyries	**0.36**	**0.35**
Alkaline intrusions	**0.20**	**0.18**
Ultramafic intrusion	**0.11**	**0.08**
Lithodiversity	**0.11**	**0.17**
Alkaline volcanics	**0.10**	**0.00**

Jaune : significant with 95% confidence

Rose : significant with 90% confidence

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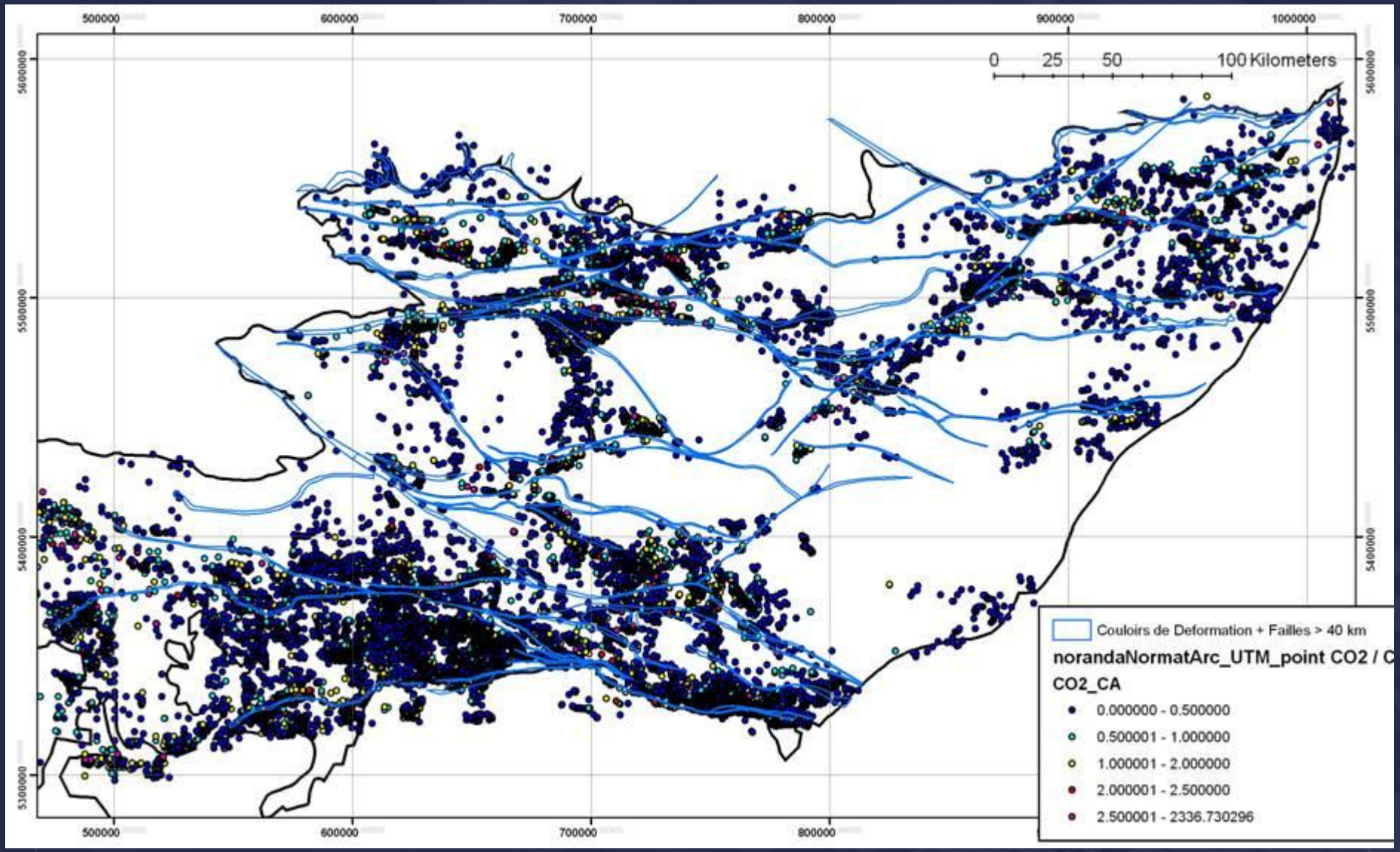
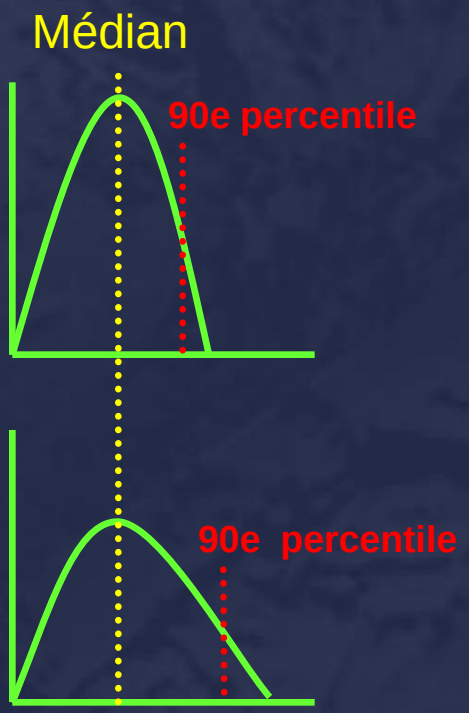
Lithogeochemical database (n=103 320 samples)



Source des données lithogéochimiques : Banque de données privée XStrata

Alteration lithogeochemical signature of DZ segments

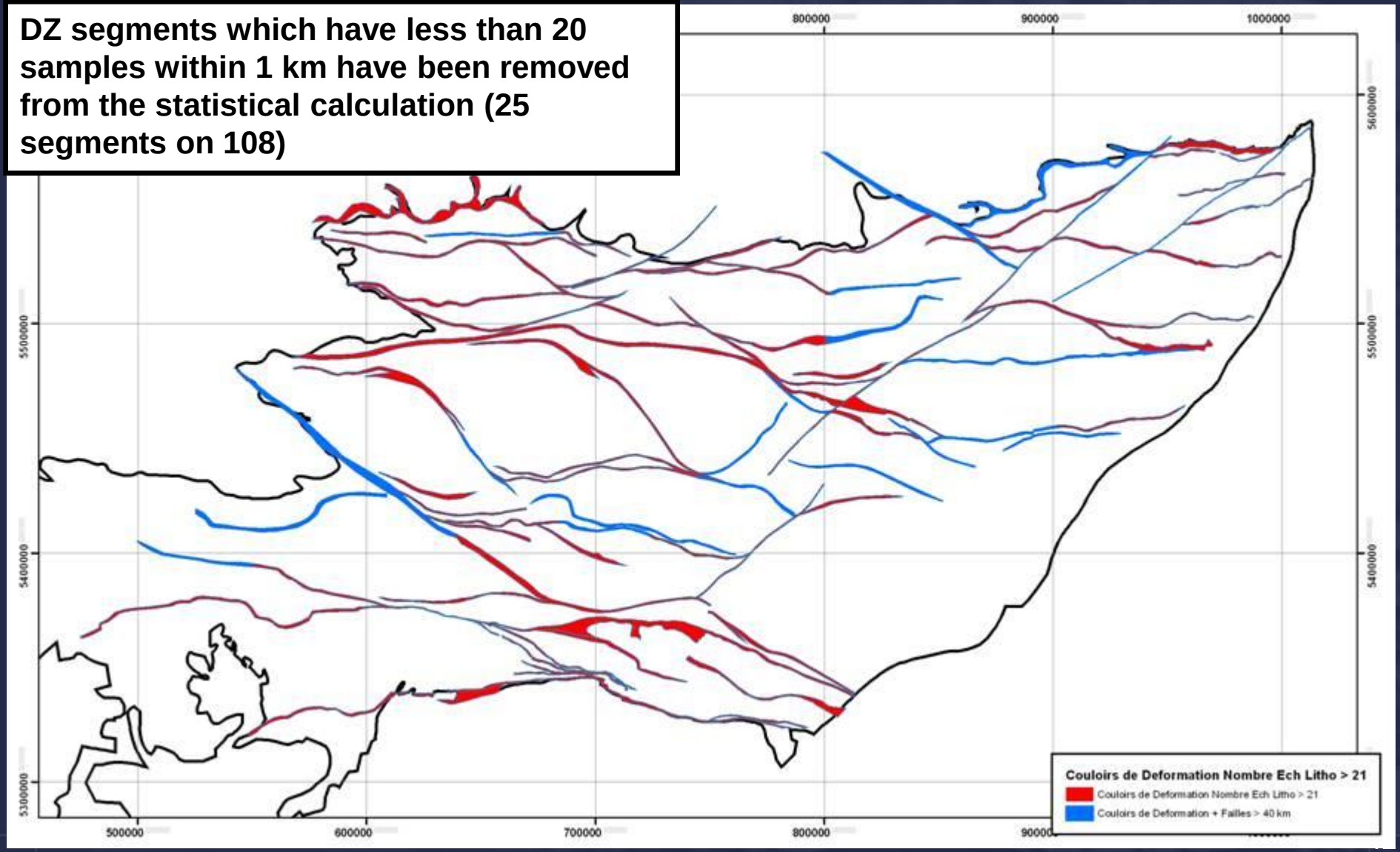
- Calculate the median value and the 90th percentile for all samples located less than 1 km from every DZ segment:
  - CO_2 / (CaO + MgO + FeO) –> Nabil, 2006 (carbonate index)
  - Normative greenschist-facies mineralogy (NORMAT) (Piché, 2004)
    - IPAF (carbonates)
    - IAB (albite)
    - ICHLO (chlorite)
    - IPARA (paragonite
    - IFRAIS (4 previous together)
    - IOR (orthoclase)
    - ISER (sericite)
    - IPYRO (pyrophyllite)
  - Number of samples



Médiane semblable
90e centile différent

Lithogeochemical database and DZ coverage

DZ segments which have less than 20 samples within 1 km have been removed from the statistical calculation (25 segments on 108)



Association between the gold content of DZ segments and regional alteration from lithogeochemistry

Pearson correlation coefficients between alteration indexes ln(gold tons) et ln (number of showings)

	Tonnes d'or	Nbre d'indices d'or
IAB 90e centile	**0.33**	**0.32**
IPAF90 + IAB90 + IPARA 90	**0.31**	**0.49**
CO2 / (CaO + MgO + FeO) Median	**0.23**	**0.43**
IPAF 90e centile	**0.22**	**0.40**
IPAF Median	**0.19**	**0.36**
IPARA 90e centile	0.18	**0.30**
IFRAIS Median	0.15	0.03
IFRAIS 90e centile	0.09	0.14
IAB Median	-0.02	-0.03
IChlo Median	0	0
IChlo 90e centile	-0.09	-0.05

	Tonnes d'or	Nombre d'indices d'or
IPARA Median	-0.12	-0.01
IPYRO Median	0	0
IPYRO 90e centile	-0.11	-0.05
IOR Median	-0.07	-0.15
IOR 90e centile	0.06	0.01
ISER Median	-0.16	-0.09
ISER 90e centile	0.1	0.14

Jaune : stastically significant with 95% confidence

Rose : statistically significant with 90% confidence

DZ segments favorable for gold

- **Multiple linear regression using the best lithogeochemical and lithological indicators**:
  - Log(%abundance) of felsic porphyry intrusions, conglomerates and ultramafic volcanics
  - 90th percentile of alteration indexes IAB (albite), IPAF (carbonates) et IPARA (paragonite)

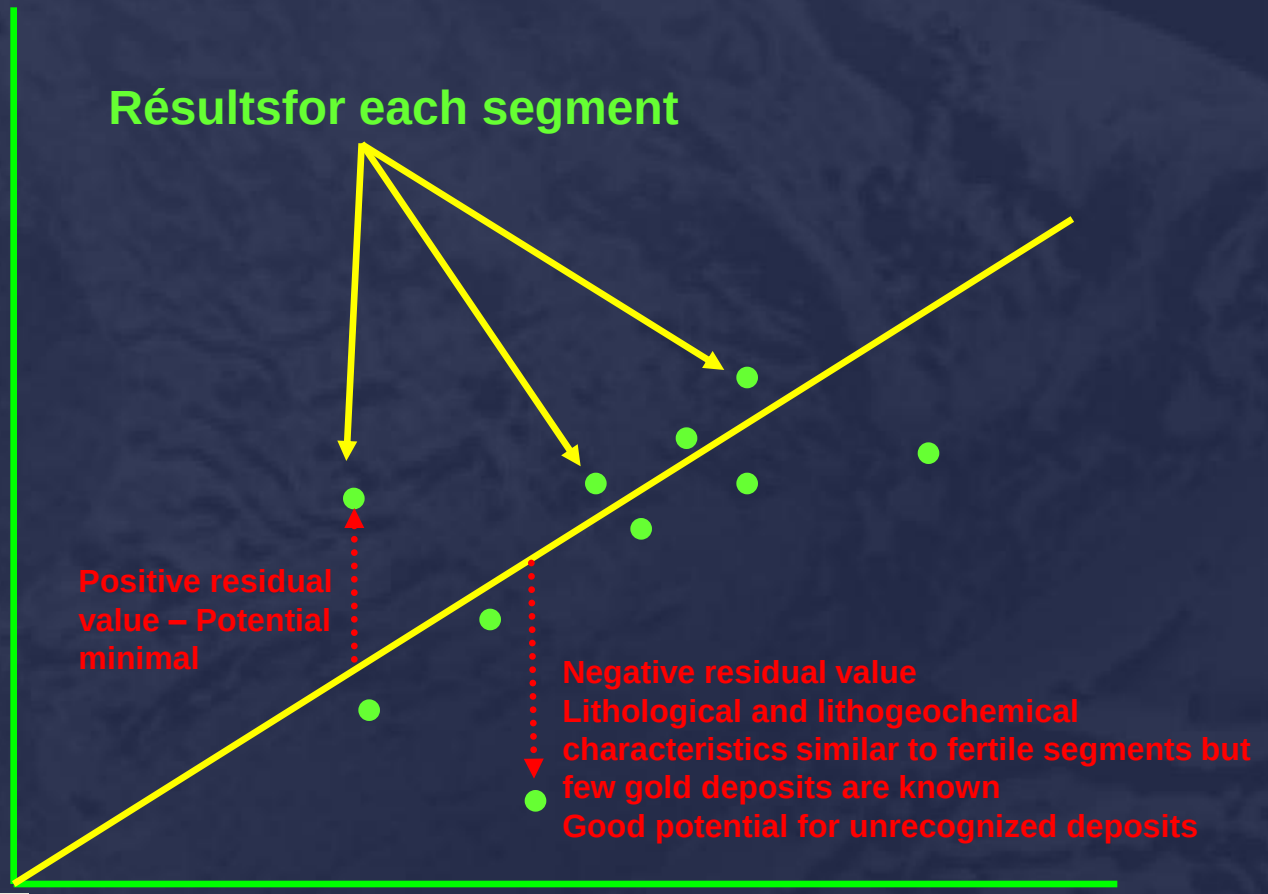
- LN_TONS_ = 1.46 + 0.252 LOG_PORPHYRIES + 0.289 LOG_CONGLOS + 0.278 LOG_VOLCUM + 0.0117 IAB_90 + 0.0146 IPARA_90 + 0.00697 IPAF_90

  - **R^2 : 0.33** → the regression explains 33% of the total variance for the number of gold tons per DZ segment
  - Relatively weak; can be explained :
    - Some segments have un-recognized potentiel (optimistic)
    - Criteria are insufficiant or vary from segment to segment

- **However, if the DZ segments which are unmineralized are excluded from the regression (i.e those with 0 tons):**
  - **R^2: 0.65 → the regression explains 65% of the total variance**
  - **Supports the idea that the criteria are sufficient and that the low R2 previously found is rather due to the unrecognized gold potential of some segments**

New segments favorable for gold-only deposits

Ln (Number of tons of gold known)



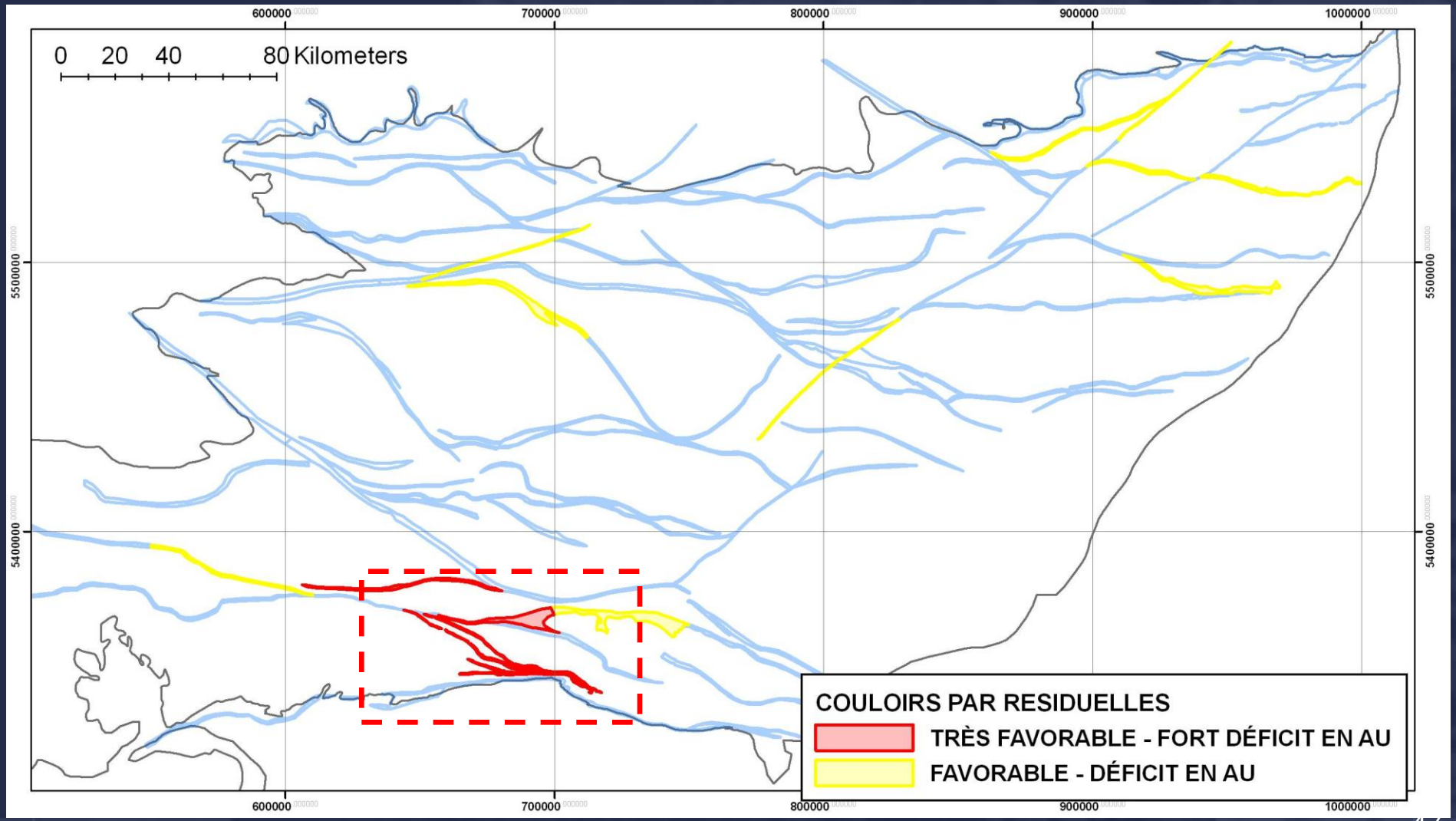
Ln (Number of tons of gold predicted by the regression)

RES_TONNES	RES_INDICES
1.439103	0.999204
1.389475	2.458793
2.891779	2.219841
-0.051282	2.155115
-1.349543	1.293719
-2.272245	-0.832748
-0.310905	0.294394
-0.004921	0.981773

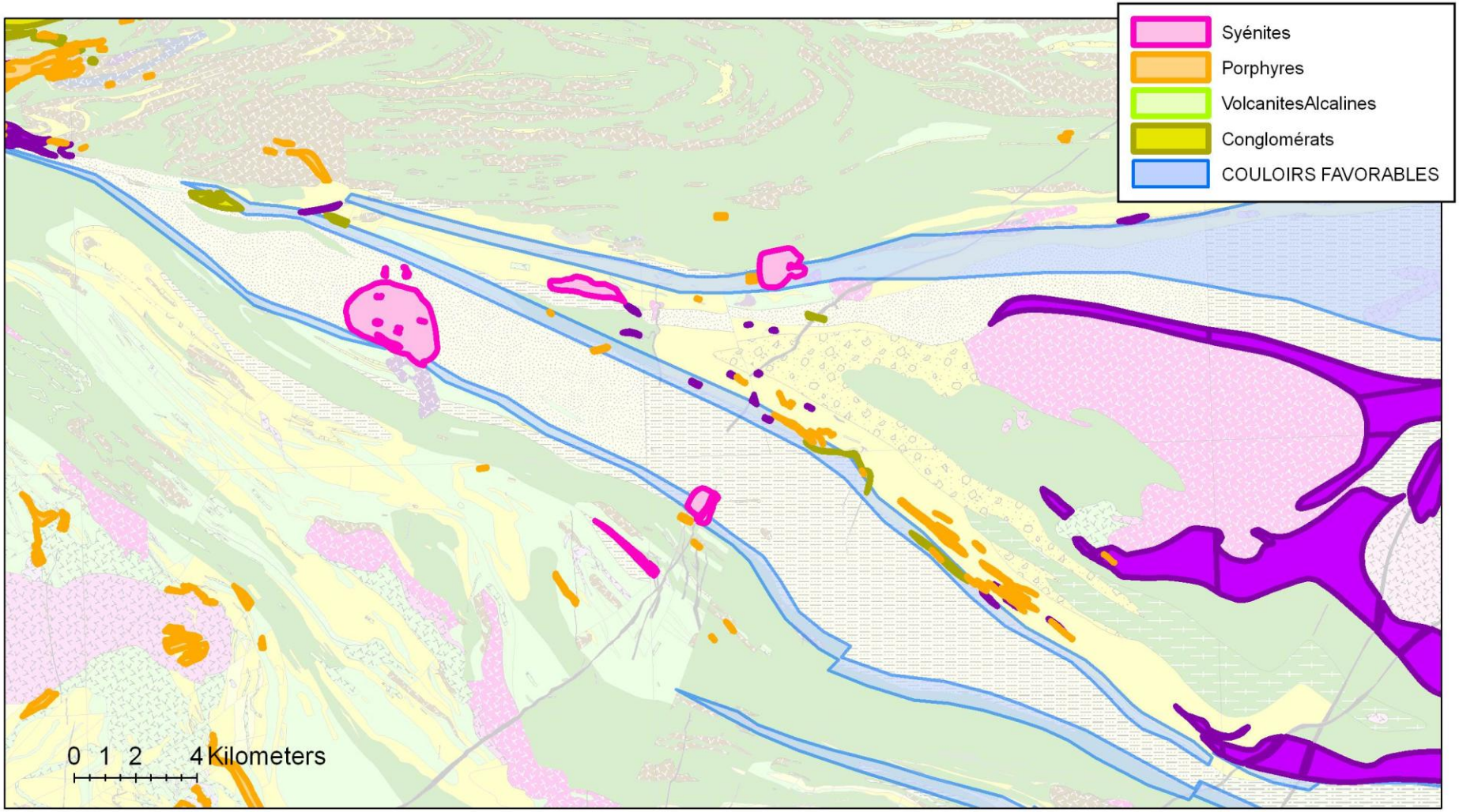
Presentation outline

- Selection and subdivision (segmentation) of deformation zones
- Calculation of the gold content of deformation zones segments
- Gold-prospectivity indicators and statistical association with the gold content of segments
  - Deformation zone classification
  - Association of various lithologies with the segments
  - Regional alteration
- Consequences for regional exploration

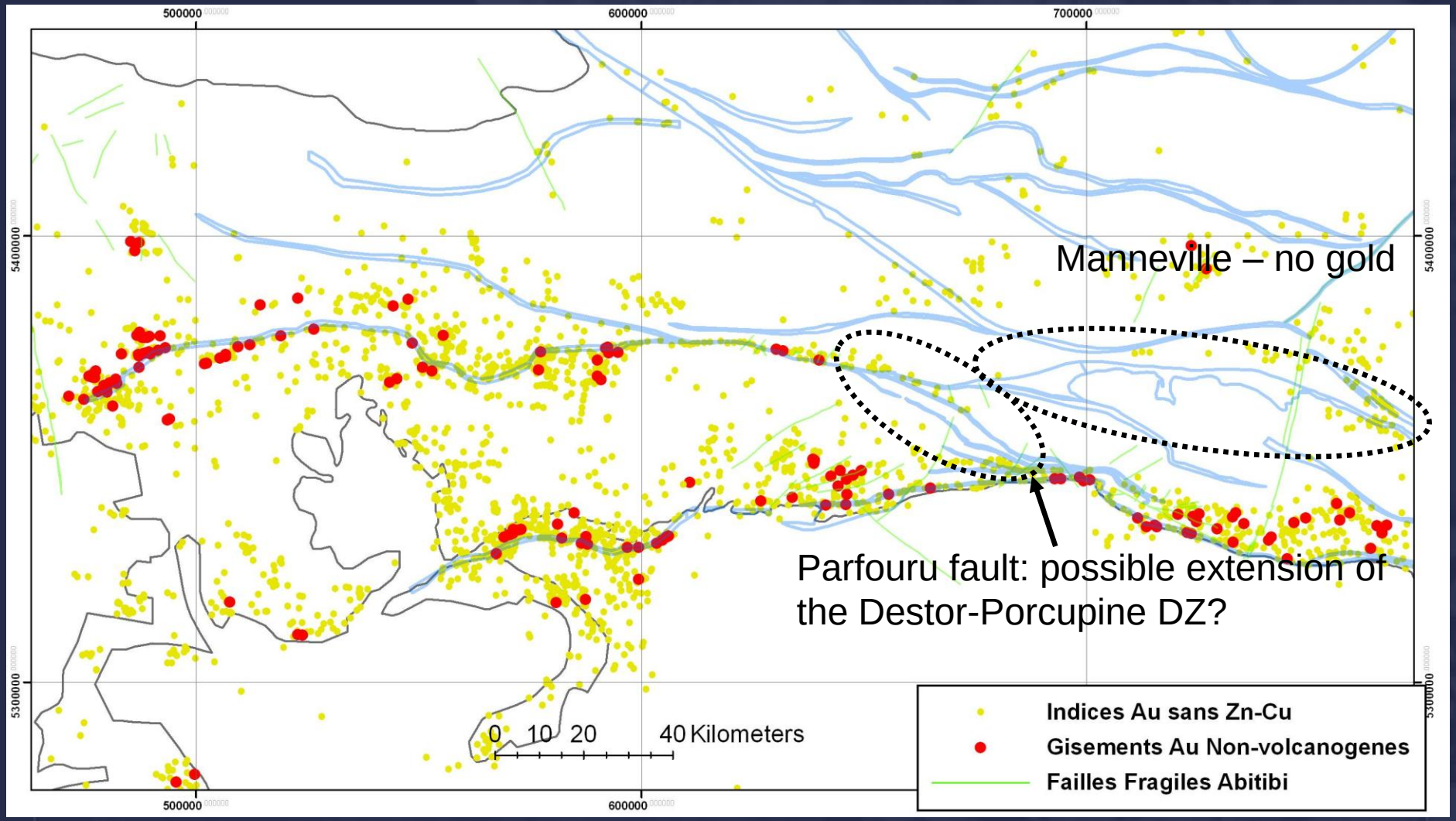
DZ segments with known gold tons less than the value predicted by the regression



Parfouru DZ – North-east of Rouyn-Noranda



Parfouru DZ – North east of Rouyn-Noranda



Conclusion

- Various critera have been used to evaluate the prospectivity of deformation zones for gold-only deposits in the Abitibi

- Some of the criteria have an excellent association with gold (both showings and number of tons of gold)
  - Abundance of ultramafic volcanics
  - Abundance of conglomerate
  - Abondance of felsic porphyry intrusions
  - Regional alteration indexes using lithogeomistry (carbonates, albite and paragonite alteration indexes)

- Somes DZ with characteristics similar to fertile DZ have lesser amounts of gold currently known and are exploration targets