Mineral exploration footprints of crustal-scale deformation zones in Neoarchean greenstone belts, Canada: fieldwork resume and first hyperspectral and geochemistry results for the Val-d'Or area

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INTRODUCTION

Orogenic gold deposits are one of the major sources of gold in the world, in particular along deformation zones in Precambrian greenstone belts. It is well known that faults are pathways for fluid during orogenic gold deposit formation. The fluid can modify and alter the host rock, leaving evidence of the fluid's flow in the rock (fig. 1).

The main objective of this study is:
to identify the physical and chemical parameters that show metasomatism through sections of major deformation zones in Neoarchean greenstone belts.

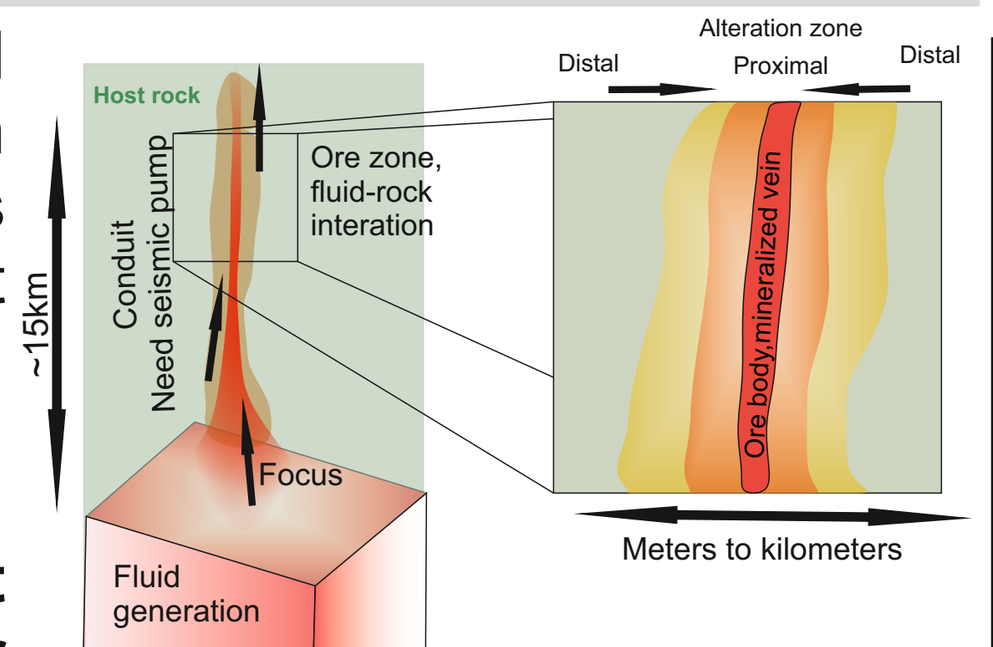
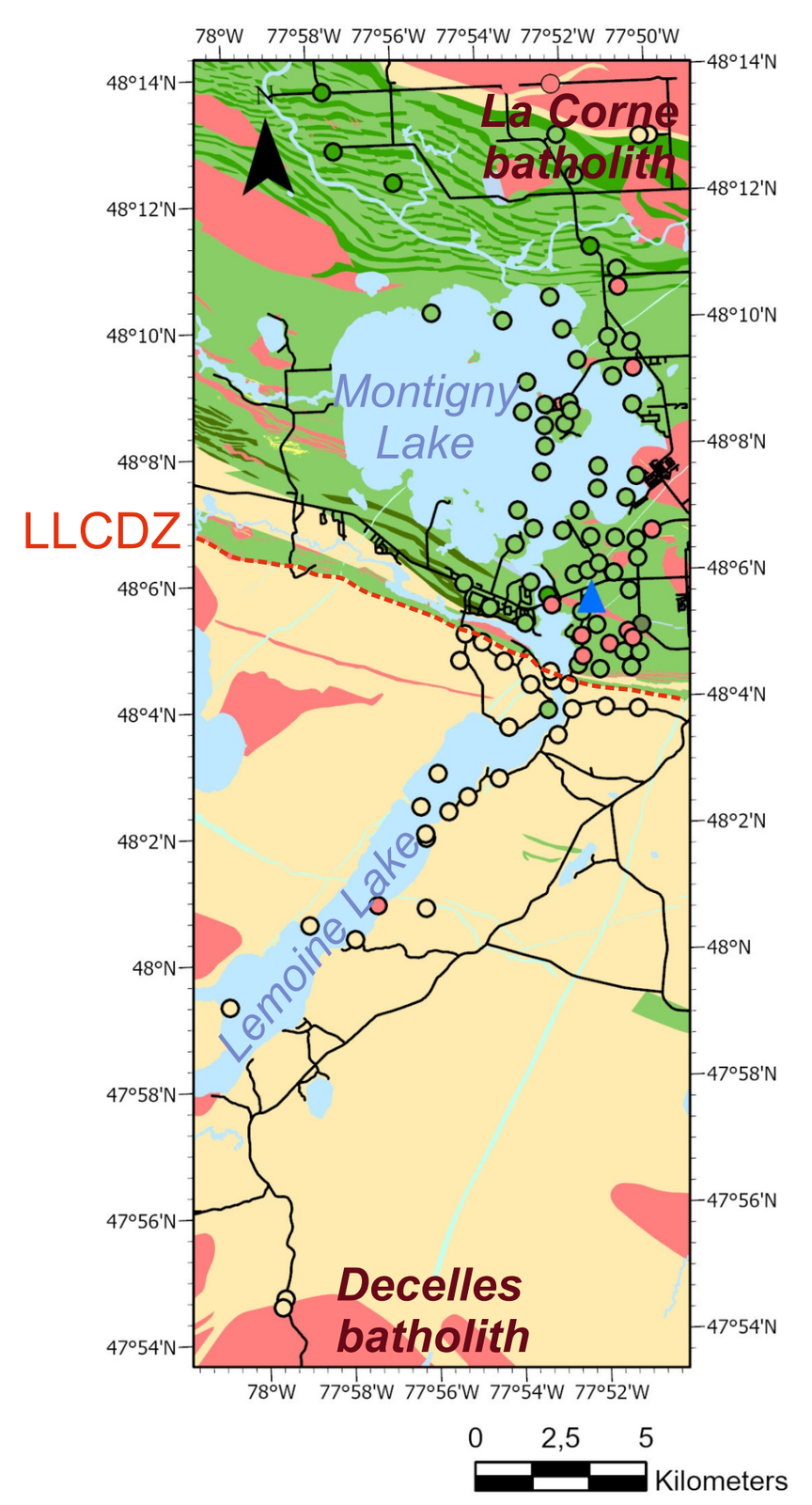


Figure 1: Schematic architecture of lode gold hydrothermal systems (modified from Ridley and Diamond, 2000).



Simplified geological and samples locations map in the Val-d'Or area

Legend
- Metaolcanic rocks (mostly mafic)
- Metasedimentary rocks
- Meta-ultramafic rocks
- Diabase dikes
- Metagabbro
- Granitoid intrusions
- Quartz veins
- Goldex location

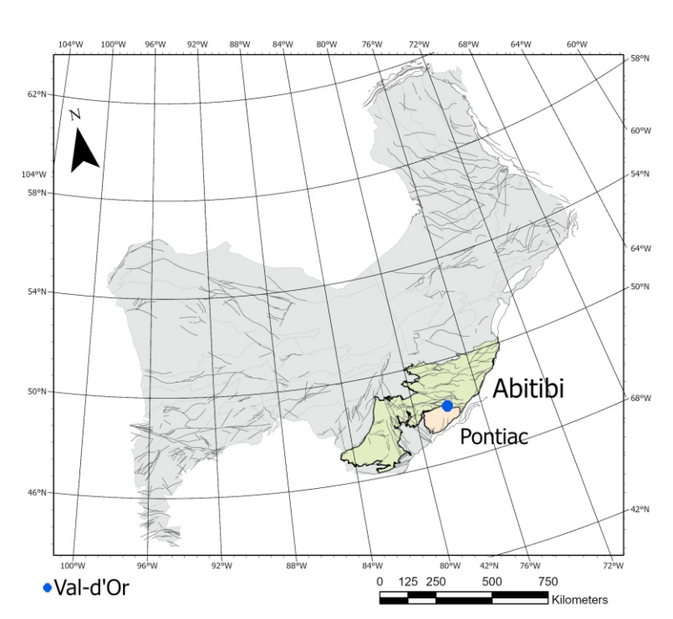


Figure 2: Simplified geological map (modified after SIGÉOM) and locations of the 139 samples collected during the summer fieldwork 2022.Location of the area within the Superior Province (modified after Montsion et al., 2018).

This study focuses on the Val-d'Or area, an example of high gold enrichment located in the Abitibi Greenstone Belt, where deposits are primarily distributed north of the crustal-scale Larder Lake-Cadillac Deformation Zone (LLCDZ) (fig. 2). The LLCDZ marks the tectonic boundary between the metavolcanic rocks (2714-2702 Ma) of the Abitibi subprovince to the north and the metaturbidites sequences (2691-2686 Ma) of the Pontiac subprovince to the south (Pilote, 2000; Scott et al., 2002; Mortensen and Card, 1993; Davis, 2002). The metamorphic grade of the Pontiac Subprovince at its northern boundary is greenschist, and increases southward, to biotite, to garnet to staurolite facies. The area is bounded in the north and south by intermediate to felsic intrusions and is crosscut by metadiorite/quartz-metadiorite.
The preliminary objectives are to:
1) Map of the intensity of the deformation.
2) Sample the main rock types for mineralogical and geochemical studies.
3) Determine elemental gains and losses and mineralogical changes related to fluid-rock interaction during the fluid migration for the different rock types.

1. DEFORMATION INTENSITY

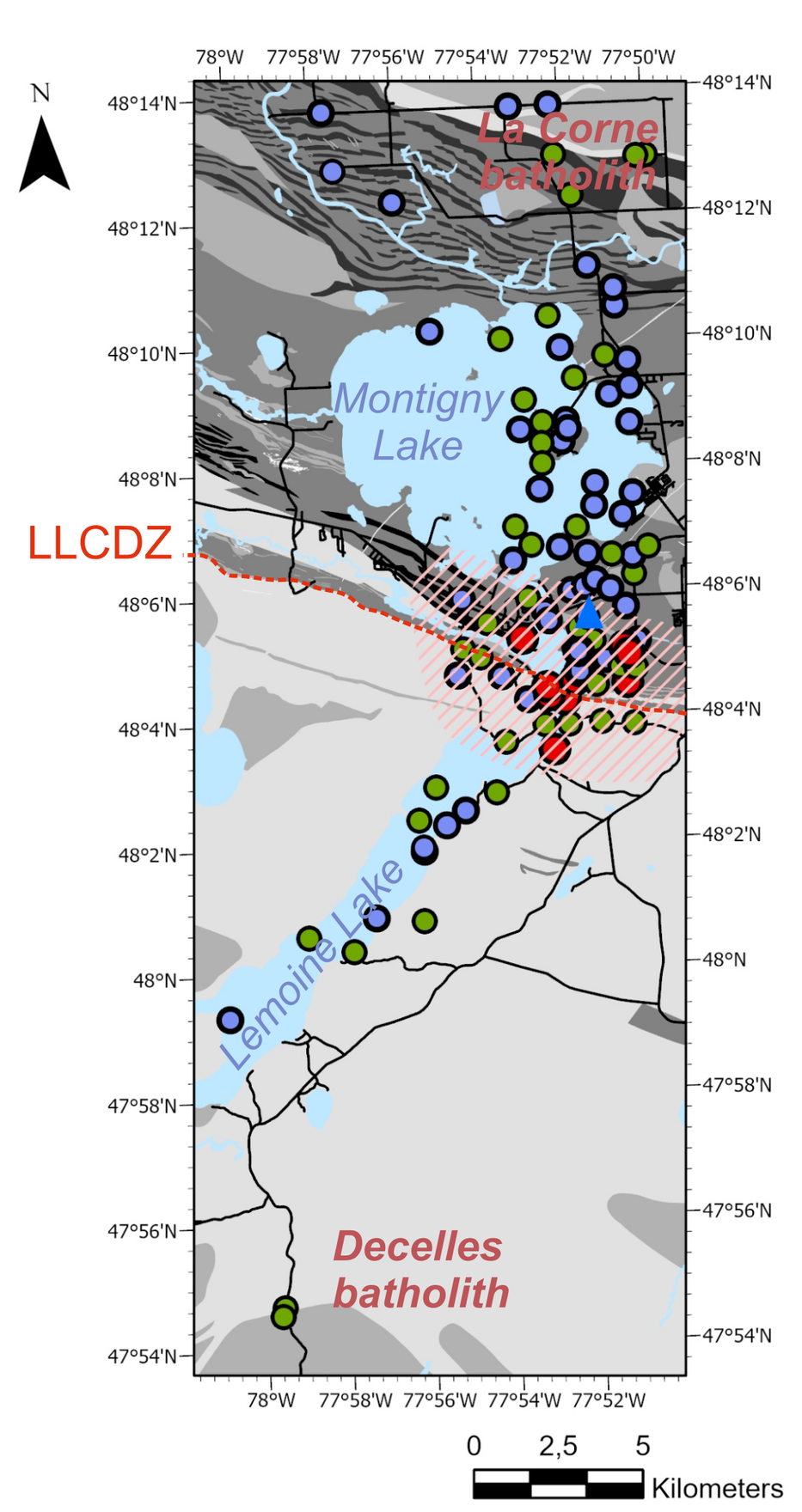
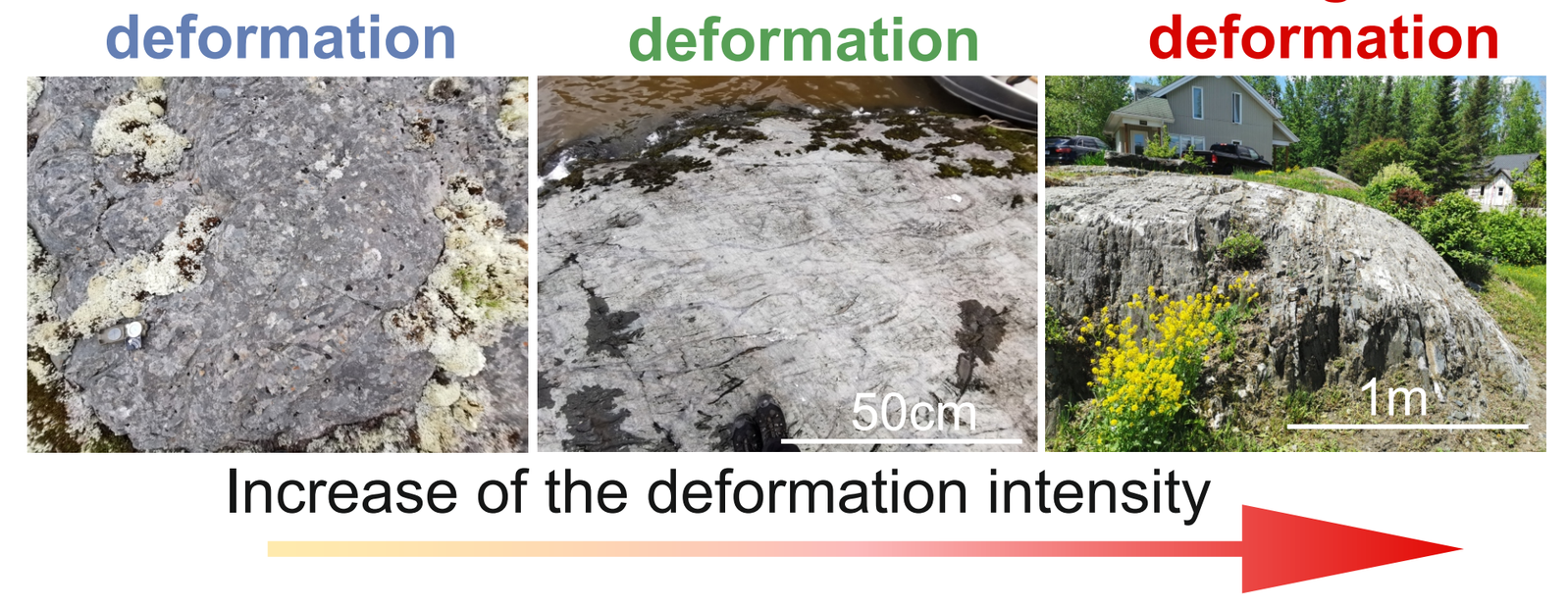


Figure 4: Map of the intensity of the deformation. The rock types are the same as in fig. 1 (modified after SIGÉOM).

Figure 3: Field scale methodology



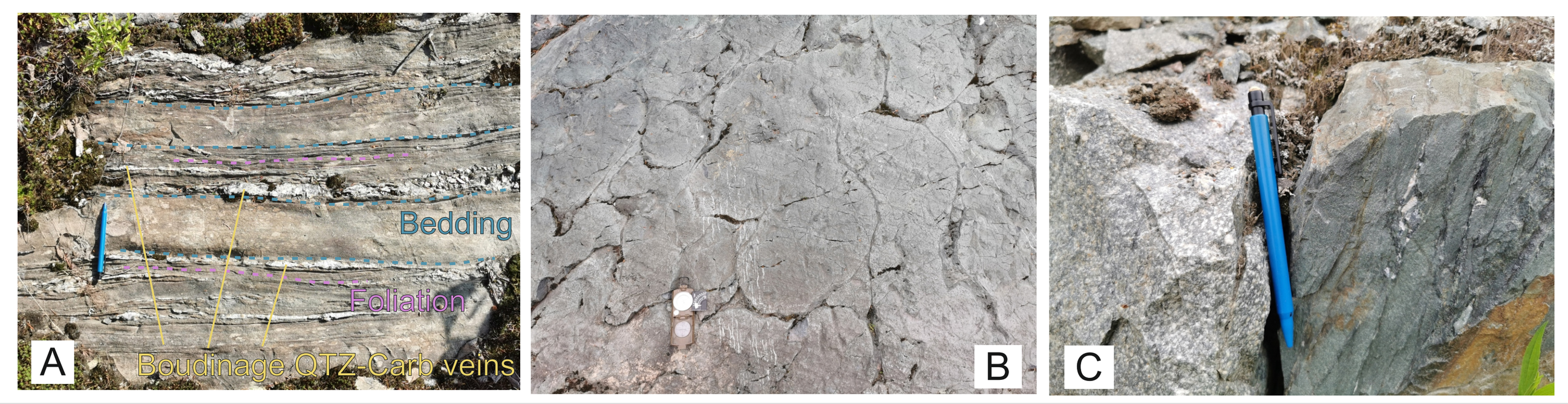
- A subjective classification scale (fig. 3) was designed to map deformation intensity in the field:
- **0: undeformed**
- **1: subtle deformation (foliation slightly visible)**
- **2: medium deformation (foliation highly visible)**
- **3: high deformation/shear zone**

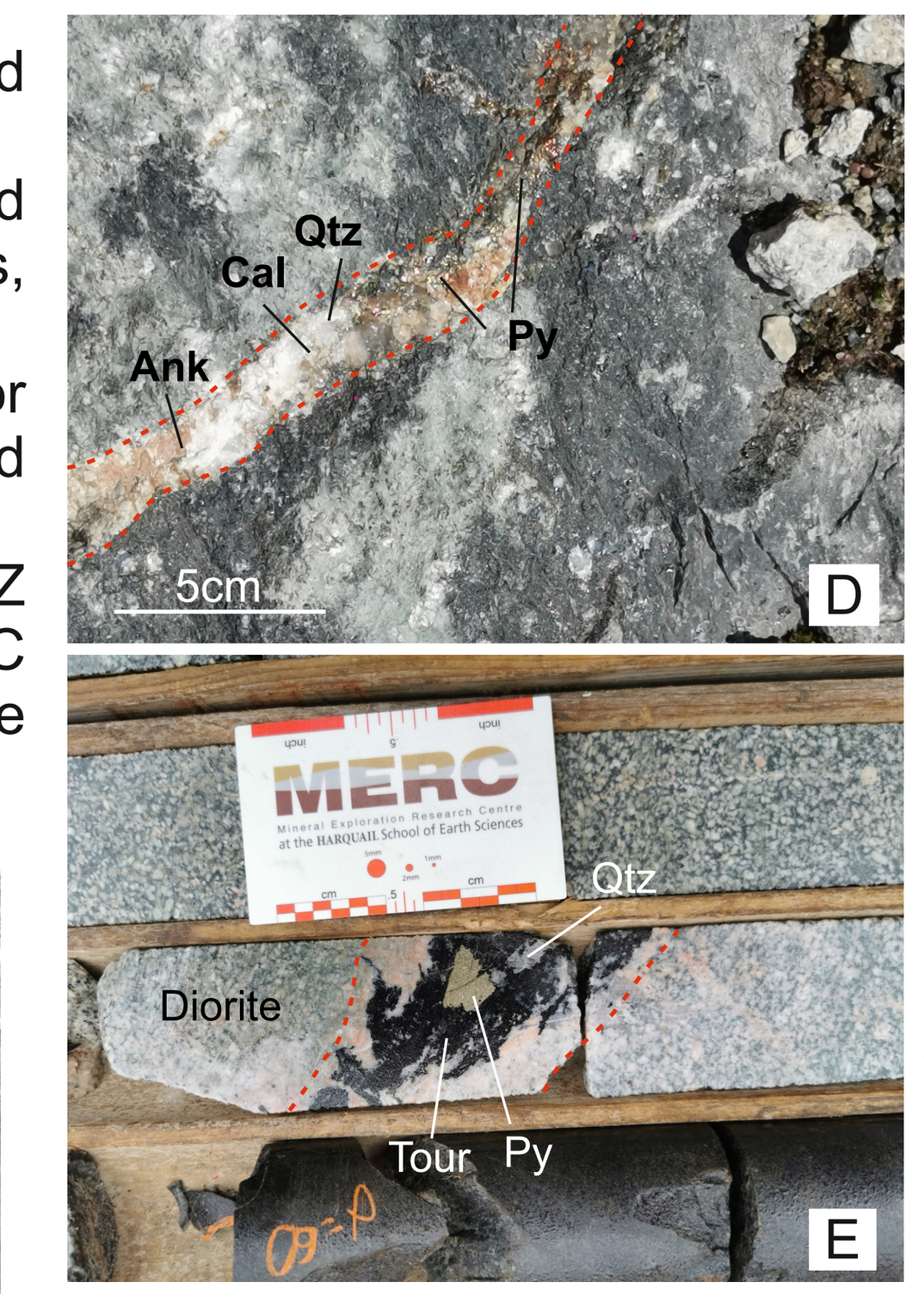
- High deformation zones are concentrated up to 2 km on both N and S side of the LLCDZ (fig. 4). Most of the veins are emplaced within the main D2 foliation at a strike of WNW-ESW. The proximal zone of the LLCDZ is characterized by high strain corridors.

2. MAIN ROCK TYPES OF THIS STUDY

This study focuses on the 3 main rock types:
- Metasedimentary rock: mudstone-siltstone alternance (fig 5A), presence of disseminated pyrite.
- Mafic metavolcanic rocks: commonly occurs as pillow (fig 5B) or massive fine grained metabasalt, from tholeiitic or calk-alcaline affinity, presence of carbonate minerals, disseminated pyrites, epidotes and epidotes heart in the pillow.
- Metadioritic to metagranodioritic rocks: plurimetric E-W trending dikes, from tholeiitic or calk-alcaline affinity, crosscut the metavolcanic rocks (fig 5C), presence of epidotes and albitization, disseminated pyrite.

All the units are crosscut by widespread quartz-carbonate (QC) and proximal to the LLCDZ quartz-tourmaline-carbonate veins (QTC). There were also noted (fig. 5D and 5E). Both QC and QTC veins can bear sulfides minerals (pyrite, pyrrhotite, minor chalcopyrite). The presence of sulfide minerals is almost systematic within the QTC veins.





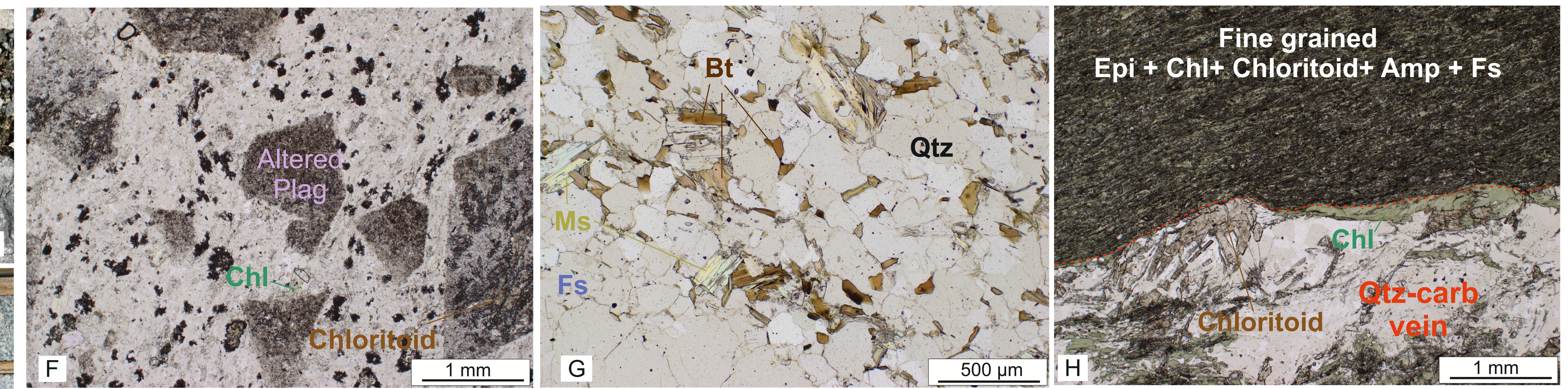
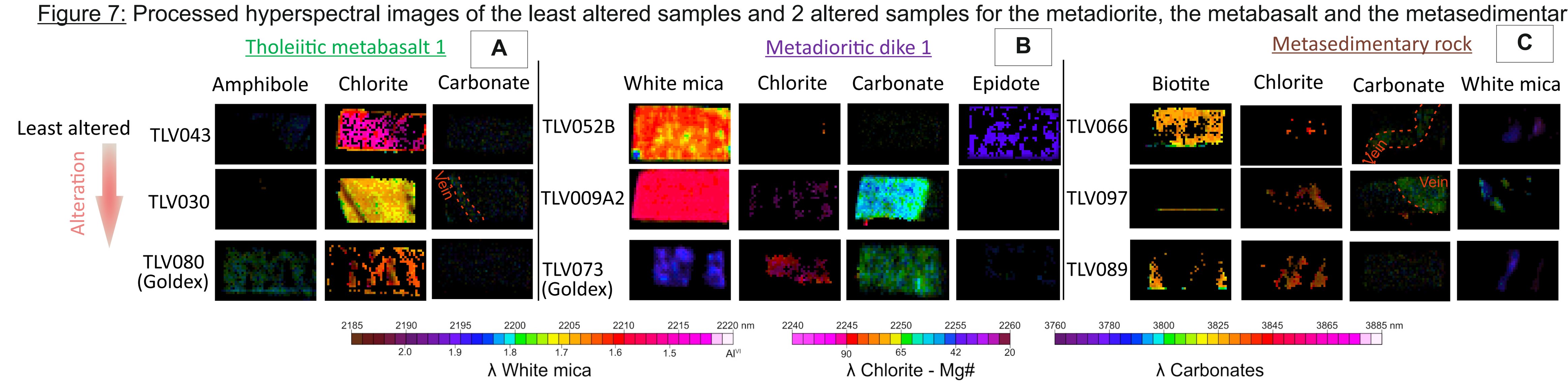


Figure 5: Macro and micro scale photographs of the main lithologies studied. (A) Metaturbidites from the Pontiac showing the foliation parallel to the bedding. (B) Pillow metabasalt. (C) Metadioritic intrusion in contact with a mafic volcanic rock.(D) Photograph of a quartz-carbonate (calcite and dolomite)-pyrite veins. (E) Photograph of a quartz-carbonate -tourmaline- pyrite photograph hosted by a diorite from the Goldex mine. (F) Plane polarised photograph of the metadiorite that was crosscut by a mafic volcanic rock. Plagioclase are replaced by epidote, chlorite and chloritoid and minor sericite. The epidote is replaced by cholrite in more altered samples. (G) Plane polarised photograph of the metasedimentary rock. (H) Plane polarised photograph of the metabasalt with a quartz vein at the bottom showing epidotes and chloritoide. Chlorite occurs mostly along the edge of the vein.

3. PRELIMINARY MASS BALANCE CALCULATION AND HYPERSPECTRAL DATA

Figure 7: Processed hyperspectral images of the least altered samples and 2 altered samples for the metadiorite, the metabasalt and the metasedimentary rock



SWIR, MWIR, and LWIR hyperspectral data (fig. 7) has been processed to image maps of the mineralogy of all of the samples.
- Tholeiitic metabasalt (fig. 7A) shows an increase of Mg# of the chlorite and of content of amphibole in samples from the Goldex mine. Carbonate minerals (moslty calcite) are found in both unaltered and altered samples.
- Metadioritic dikes (fig. 7B): with a decreasing distance to the Goldex mine the altered samples show: white mica that changes from phengite to muscovite compositions (increase of the Al content) , decrease of the epidote content, increase of the chlorite and carbonate minerals content (mostly calcite).
- Metasedimentary rock (fig. 7C): decrease biotite content , increase of the chlorite content, carbonate are found in veins, decrease of the Al content in the white mica.

Elemental gains and losses: (fig. 8)
- Considered least mobile elements:

metasedimentary rock	metabasalt	metadiorite
Tm, Yb, Zr	Al, Ti, Y	Zr, Y

- Global gains of Au, Te, As, Se, Mo, W, S, C and a loss of K_2O are seen with all of the altered samples.
- Altered metasedimentary samples have undergone a loss of LILE.
- Altered metadioritic samples have undergone a gain of LREE, and a loss of Cu.
- Metabasaltic samples have undergone a loss of LILE.

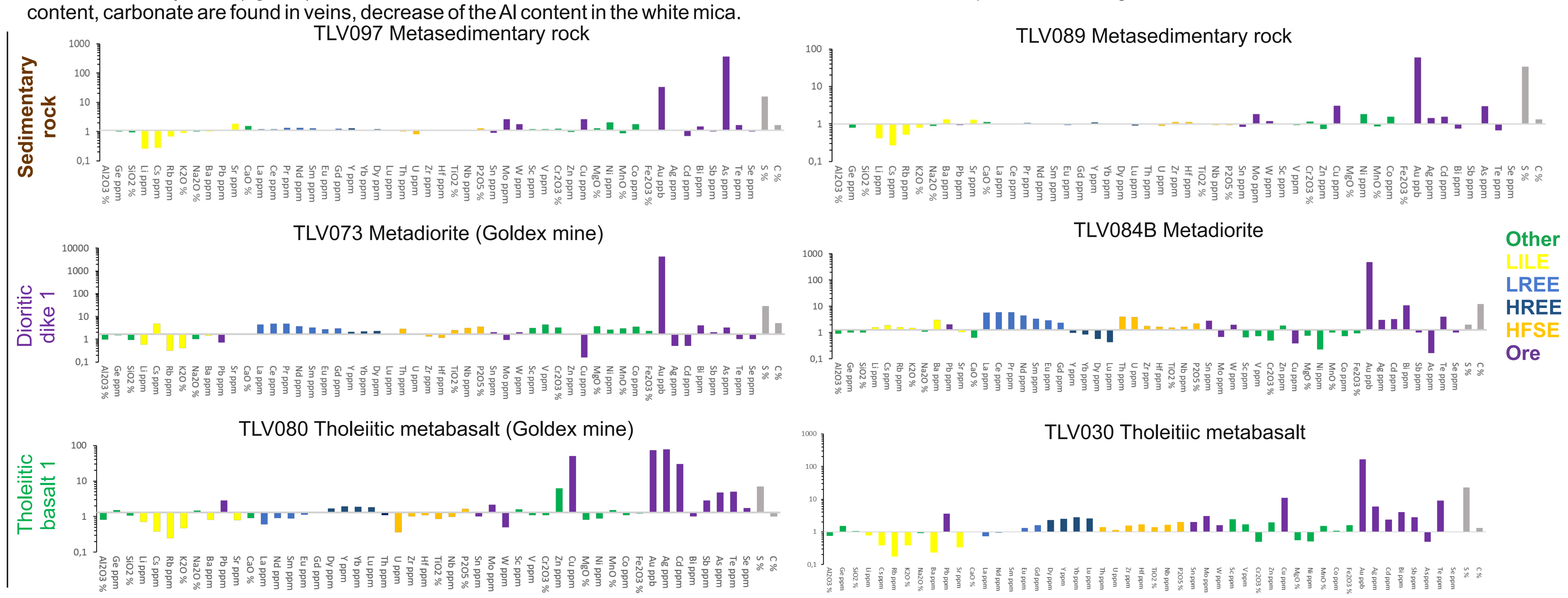


Figure 8: Elemental gains and losses for altered metasedimentary, metabasaltic, metadioritic samples. using the MacLean method (MacLean, 1990). The elemental gain and loss is given by ΔZ = (Z least altered/Z unaltered) (where Z is the elemental concentration).

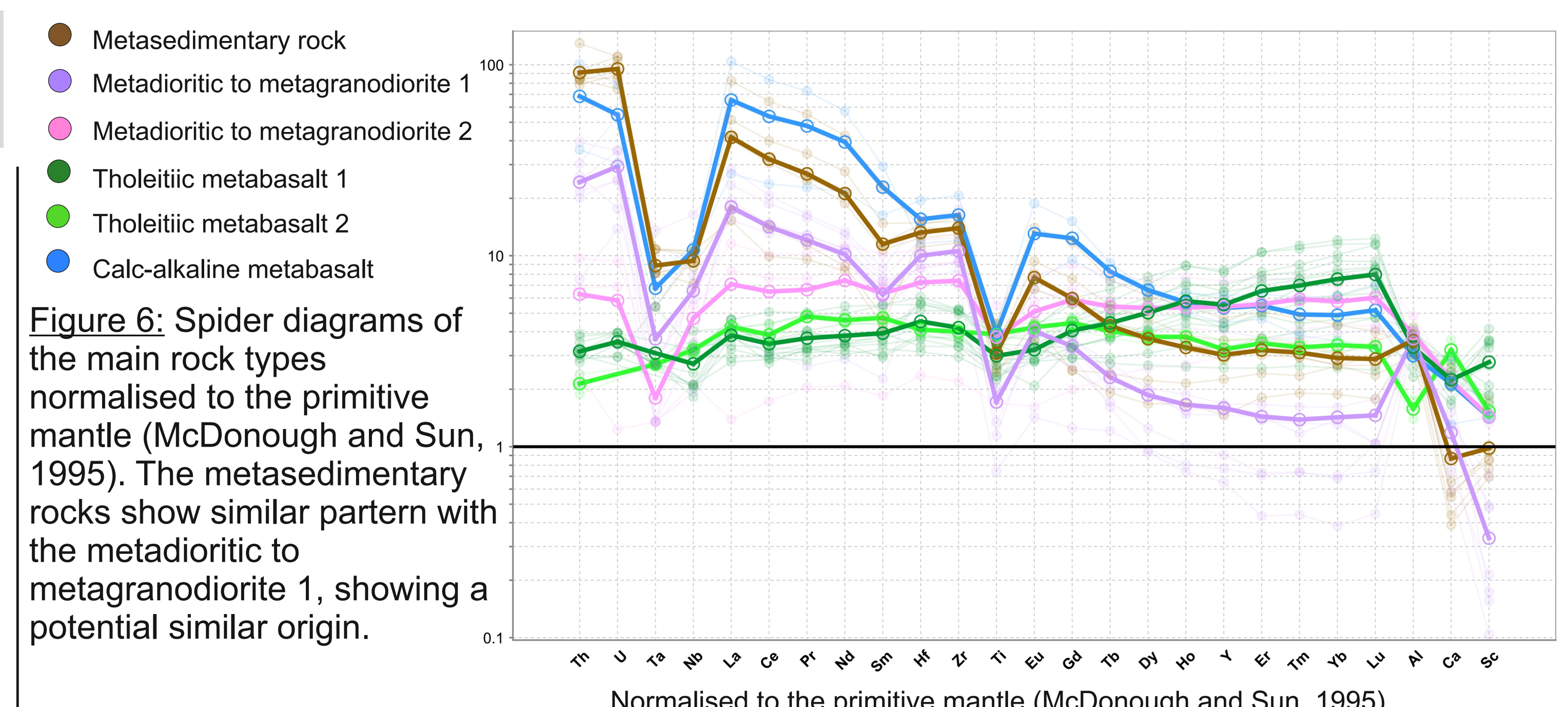


Figure 6: Spider diagrams of the main rock types normalised to the primitive mantle (McDonough and Sun, 1995). The metasedimentary rocks show similar partern with the metadioritic to metagranodiorite 1, showing a potential similar origin.

CONCLUSIONS

The combination of field work, hyperspectral and geochemistry data leads to a better understanding of the relationship between deformation and the fluid-rock interaction/alteration during the formation of an orogenic gold deposit.
As the gold in the area is first emplaced and then remobilized, the host rocks undergo multiple alteration events (Genest et al., 2012; Herzog et al., 2022). The mineralogical changes and elemental gains and losses showed in this study do not differentiate the different alteration events.

Takeaway points:
- Veins are mainly parallel to the foliation with a NW-SE orientation (D2 event).
- The high intensity deformation zone is located up to 2 km both north and south of the LLCDZ.
- The alteration is controlled by the rock type. However, a global gain in elements commonly associated with the gold (label in purple) and a loss in K_2O is visible as the alteration increases.
- Metabasalt and metadioritic dikes undergo a carbonatization.
- Metadioritic dike seems undergo a transformation of epidote into chlorite.

Next step for the future:
- Mineral chemistry of quartz and pyrite to investigate a specific chemical signature.
- Establishing a sequence of the alteration.
- Geothermometry to investigate whether there is a thermal gradient across the deformation zone.
- Comparison with the poorly endowed Wabigoon Deformation Zone in Dryden.

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SIGÉOM

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