Using modern field mapping techniques to characterize magmatic-hydrothermal IOCG deposit alteration zones in a Lower Cretaceous Peruvian pluton

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Introduction:

The Cerro Media Luna Pluton (CMLP) is part of the Mesozoic Peruvian Coastal Batholith (PCB) near Pisco in Western Peru (Fig. 1). The CMLP has been considered a Cu porphyry (CP) system based on rock sample description of reddish or pinkish rocks. However, the PCB includes part of the 180-100 Ma Andean Iron Oxide-Copper-Gold (IOCG) belt. Though the mineralization of CP and IOCG systems are very distinct, they have some similarities between the alteration assemblages. Potassic, sericitc, and propylitic alteration are common features of both, but sodic-calcic alteration, U content, and iron oxides (especially hematite and magnetite) are specific characteristics of IOCG deposits. The attempt of this research is to characterize the hydrothermal system using modern mapping and analytical techniques. This approach allows for quicker preliminary conclusions and will impact the way we look for mineral resources.

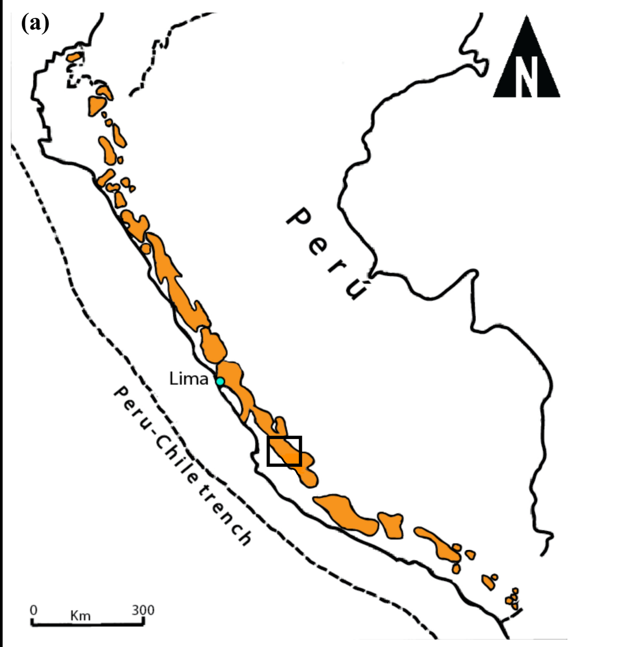

Table 1: Preliminary alteration zones based on petrographic description.

Zone	Iron Oxides	Other Main Minerals	Accessory Minerals
1	Mgt > Hem	Qz	Sd ± Ank
2	Mgt > Hem	Ep	Sd
3	Mgt	Act + Ep + Chl	FK
4	Hem > Mgt	Qz	Sd ± Ank
5	Hem	Ep	Qz ± Sd ± Ank

Abbreviations: Act: Actinolite; Ank: ankerite; Chl: Chlorite; Ep: epidote; ; FK: k-spar; Hem: hematite; Mgt: magnetite; Qz: quartz; Sd: siderite.

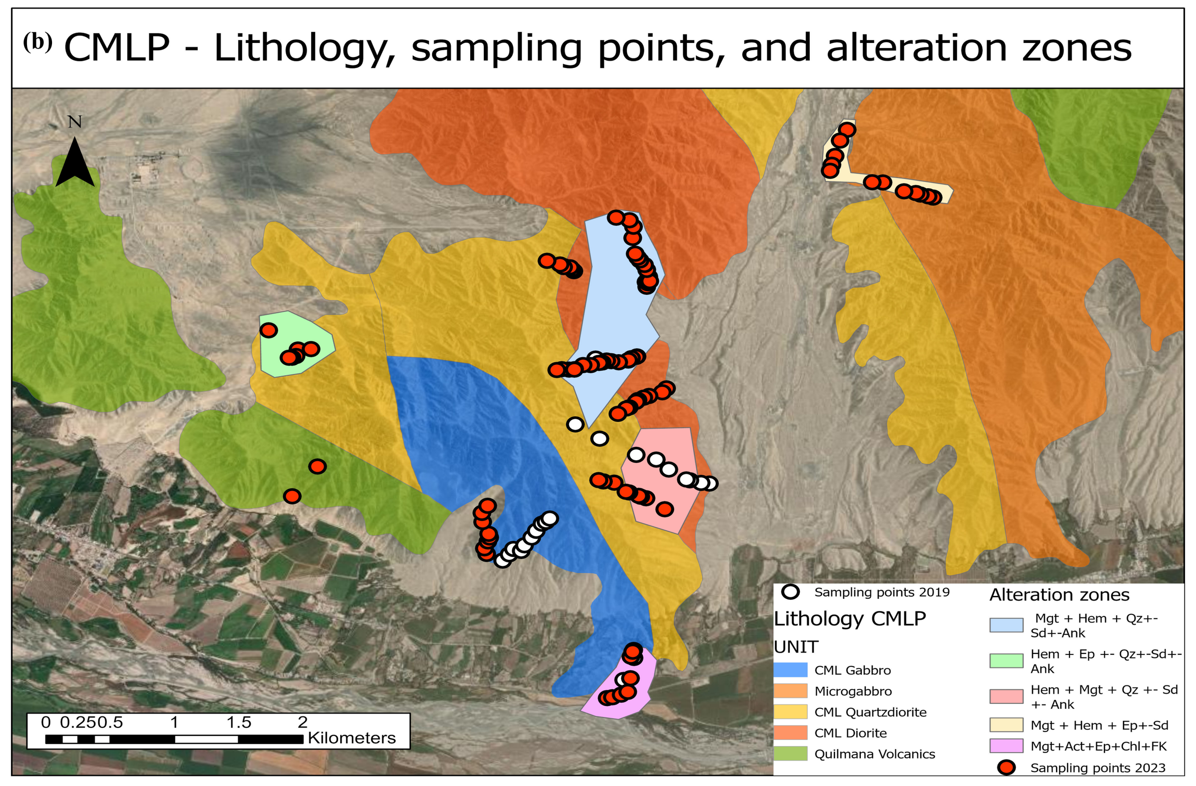

Fig. 1: (a) Location of the studied area in relation to PCB igneous events. Red square represents the CMLP area and (b) CMLP map and its geologic units, sampling point across the years and alteration zones based on field description

Methods and Results:

To characterize the CMLP magmatic-hydrothermal system, hand sample description was used, but with the addition of GIS methods assisted by Strabospot 2, magnetic susceptibility (MS) meter, and portable gamma spectrometer (GS). In the lab the samples were analyzed with an infrared (IR) spectrometer.

Field observations:

According to field work descriptions, five preliminary zones have been constrained based on the described mineral assemblage, as shown in **Table 1**.

Field observations:

Fig. 2: (a) Gamma Spectrometry measure of outcrop, (b) redish sample from microgabbro unit, and (c) pinkish vein from diorite unit. .

Gamma spectrometry shows low and constant values of K across the plutonic units irrespective of the type of sample analyzed (vein or host rock), whereas U content was moderately high and the highest values are representing some of the collected vein samples. The values of MS show no correlation concerning sample type. Data is reported in **Fig. 3**.

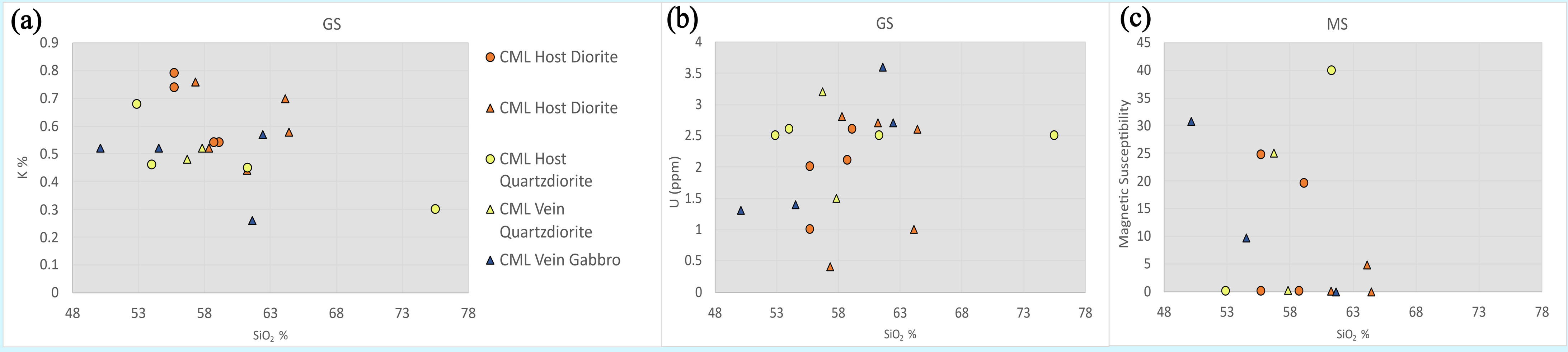

Fig. 3: (a) Cerro Media Luna Pluton Gamma Spectrometry for K, (b) Cerro Media Luna Pluton Gamma Spectrometry for U, and (c) Magnetic Susceptibility data collected in the field. Circles represent host rocks and triangles represent veins.

Laboratory work:

Terraspec IR analyses of 100 samples confirmed the presence of iron oxides and iron carbonates in our samples, as **Fig.4 (a)** shows. XRD analysis of diorite unit's vein sample show low amount of k-spar, as Fig. **4(c and d)** show.

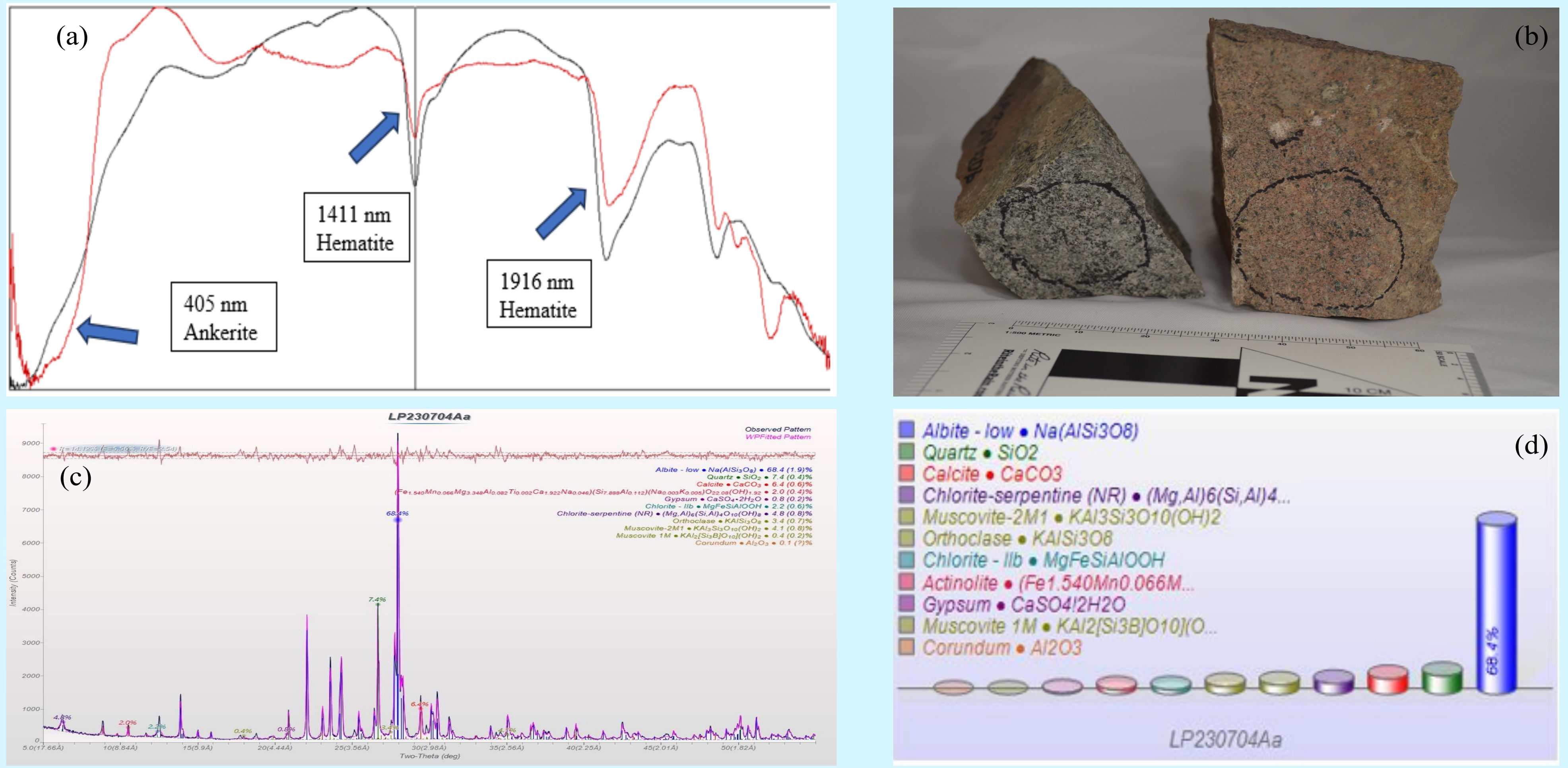

Fig. 4: (a) IR spectrum of sample from northern part of diorite unit. Red line represents the sample's spectrum and black line represents reconciled spectrum; (b) Comparison between fresh rock and pink (altered) rock sampled in the northern part of diorite unit, (c) XRD spectrum of sample collected at the eastern margin of diorite unit, and (d) Mineral percentage in sample collected at the easthern margin of the diorite unit.

Laboratory work:

Whole rock analyses by ICPMS and XRF (major and trace elements). CaO and Na_2O plots show trends very similar to the ones of magma undergoing the differentiation process, as shown in **Fig. 5**.

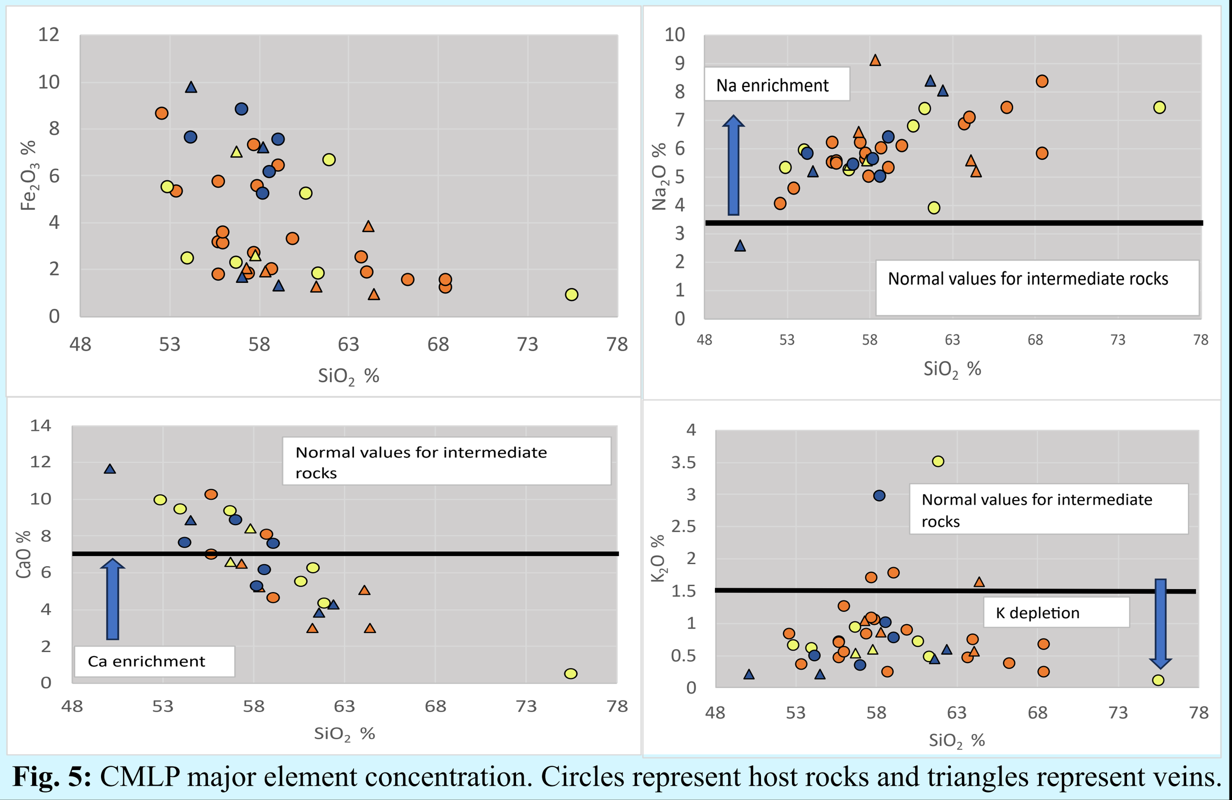

Fig. 5: CMLP major element concentration. Circles represent host rocks and triangles represent veins.

Discussion:

The GS results show very low values of K, including among the veins, which suggests that potassic alteration is not one of CMLP's strongest alteration assemblages. Along with it, some of the veins are enriched in U content, that is one of the possible features of an IOCG deposit. The oscillation of MS also suggests zones of enrichment of magnetite, which is expected from an IOCG due to the zones rich in magnetite (where MS values are higher) and hematite (where MS values are low), as **Table 1**, **Fig. 3 (c)**, and **Fig. 6** show.

As shown in the Harker diagrams (Fe_2O_3), the concentrations don't form a linear trend, which suggests hydrothermal alteration. Apart from that, the samples that plot above normal concetration values for CaO suggest the calcic alteration; most samples plot below normal concentration values for K_2O, which corroborates gamma spectrometry results and suggests low importance of major element in the pluton; and all samples, but one, plot above normal concentrations for Na_2O, which suggests sodic alteration. Within the silica range of 53-58%, sodic and calcic are suggested as alteration type, which is expected from an IOCG deposit, as shown in **Fig. 6**. Also, IR and XRD show insignifcant K-spar, which corroborates that the mineralization is not similar to a copper porphyry type.

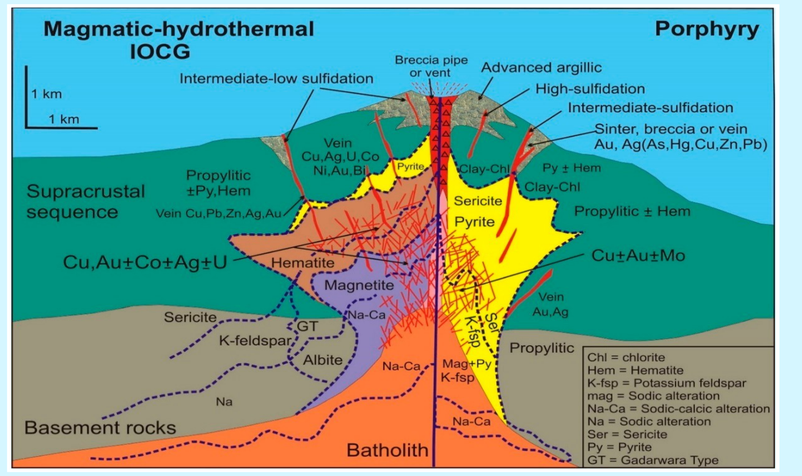

Fig. 6: Schematic drawing comparing IOCG deposits (left side) and CP deposits (right side), from Raju and Kumar (2020). Each side represents the alteration zone found in each type of deposit and the specific more important minerals of each deposit.

Conclusions:

This study validates the proposed method by correlating *in situ* and laboratory measurements. The method's precision in assigning chemical signature aids informed decision-making on alteration zones and potential ore bodies within a batholith. Future steps involve method consolidation through repeated applications to diverse ore bodies. Results suggest the studied area resembles an IOCG type deposit rather than a CP deposit based on the following:

- Low K, high U, and Na-Ca alteration presence
- Magnetic and non-magnetic zones associated to the Fe_2O_3 concentration
- Low percentage of k-spar and presence of reddish or pinkish color due to iron carbonates.

References:

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