

Application of the Thermo Scientific Portable XRF Analyzer in Geochemical Exploration: An Example from the Francisco I. Madero Zn–Pb–Cu–(Ag) Deposit, Zacatecas, Mexico

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Overview

This field and lab-based research was conducted to compare assay results from different analytical methods and investigate application and efficiency of portable x-ray fluorescence (XRF) in base and precious metal mining.

Three types of analyses were carried out on drill core samples. These methods include in-house Madero atomic absorption (AA), ALS inductively coupled plasma emission spectroscopy (ICP-ES), and Thermo Scientific portable XRF (Thermo Scientific handheld Niton XL3t GOLDD+ analyzer and Niton® FXL field x-ray lab) on pulp samples as well as direct shot (scanning) on core specimens.

This investigation shows high correlation between data from portable XRF and lab methods for all metals of interest in this deposit (Zn-Pb-Cu-Ag). In the prepared samples, the correlation is as high as 98% for Pb, 97% for Zn, 96% for Cu, 80% for Ag. In addition, this study emphasizes the effect of sample preparation in the accuracy of data. For example, in core samples analyzed by direct shot (scanning), correlation between data from Thermo Scientific handheld Niton XL3t GOLDD+ and lab method (AAS) is only 72% for Zn. This correlation jumps to 96% on pulverized samples. Geochemical anomalies of not only base and precious metals but also light elements such as Al and S can be detected easily by systematic analyses of core samples using portable XRF analyzers.

Introduction

Francisco I. Madero is a Zn–Cu–Pb–(Ag) deposit owned by Peñoles and operated as an underground mine in Zacatecas, central Mexico (Figure 1). Historical production up to 2011 is 23.1 Mt of ore containing 12.8 MoZ Ag, 92.09 kt of Pb, and 623.9 kt of Zn. The deposit consists of several mineralized zones located around a dome-type structure (laccolith) probably generated by forceful emplacement of an intrusive body at depth, which shows a wide magnetic and gravimetric anomaly; however, the only intrusive rocks found in the mineralized area are a few Tertiary, post-Laramide dikes. The mineralized area is ~10 Km² with several ore bodies located in the same stratigraphic unit from 30 to 690 m at depth. The stratabound ore bodies are hosted by the Mesozoic back-arc marine sedimentary rocks, suggesting a syngenetic submarine exhalative genesis as sedimentary exhalative (SEDEX) or volcanogenic (VMS). However, calc-silicate mineralogy and replacement textures within calcareous units, and the absence of exhalites or identifiable feeder zones, favors distal skarn model (Caneta et al., 2009).

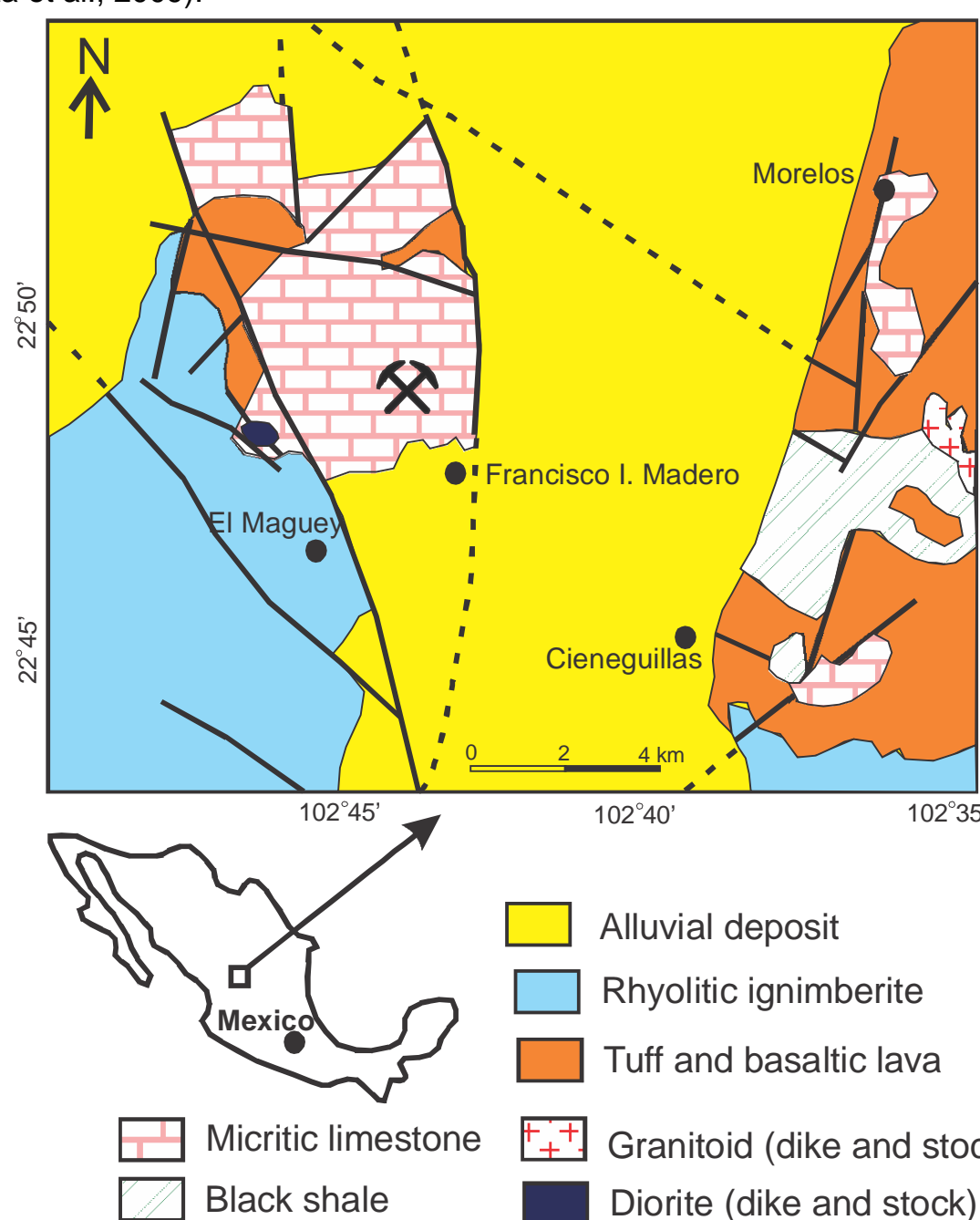


FIGURE 1. Geological map of the Francisco I. Madero Zn–Cu–Pb–(Ag) deposit, Mexico.

There are two types of sulfide ore assemblages in the ore body: 1) Pb–Zn sulfides as NW trending 6–65 m thick masses composed of bands and laminations of sphalerite and galena cut by quartz, clay-pyrite, and chlorite-epidote veins at the base of the ore body in an area of 6 km², and 2) Cu–Ag sulfide assemblage consists of chalcocopyrite, pyrite, cubanite, enargite, and tetrahedrite as laminations and bands in 3–40 m thick ore masses cut by quartz-pyrite-chalcocopyrite veinlets (Figure 2). Propylitic alteration is common (Figure 2). Occurrence of the ore zone between an impermeable shale at the bottom and limestone layers at the top (Figure 3) indicates stratigraphic control on ore emplacement.

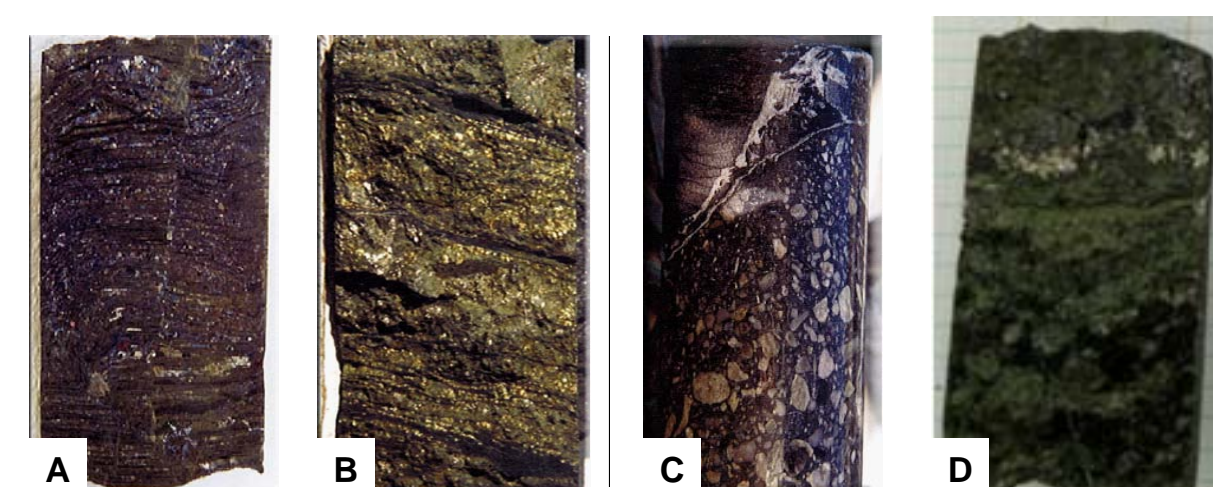


FIGURE 2. A-B) Pyrite-chalcocopyrite mineralization C) Mineralized breccia along a normal fault D) Propylitic (epidote-chlorite) alteration

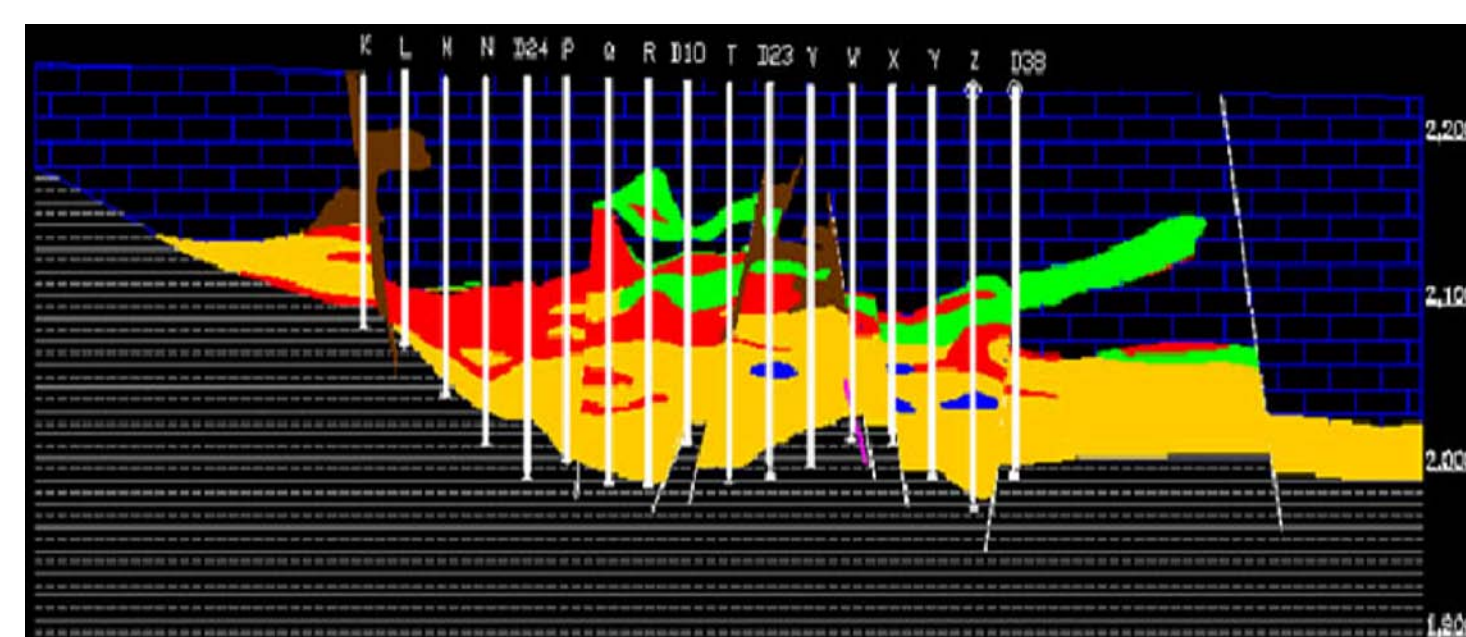


FIGURE 3. Geometry of the ore zone is indicated by drill holes. Note the localization of this zone between a shale unit at the bottom and limestone units at the top.

Method

To compare assay results from different analytical methods and investigate application and efficiency of portable XRF in base and precious metal mining, specimens were collected from eight drill holes:

- Drill hole C49-11 - Samples 240100-240190
- Drill hole C49-12 - Samples 240191-240223
- Drill hole C49-13 - Samples 240224-240262
- Drill hole C49-15 - Samples 240263-240298
- Drill hole C49-16 - Samples 240299-240327
- Drill hole AD 63 - Samples 239565-239609
- Drill hole AB 65 - Samples 239610-239645
- Drill hole AB 63 - Samples 239646-239679

Three types of analyses were carried out on each sample (Figure 4).

1. In-house Madero atomic absorption (AAS)
2. ALS inductively coupled plasma emission spectroscopy (ICP-ES)
3. Thermo Scientific portable XRF
 - A. Niton XL3t GOLDD+
 - I. On pulp
 - II. Direct shot (scan)
 - B. Niton FXL on pulp

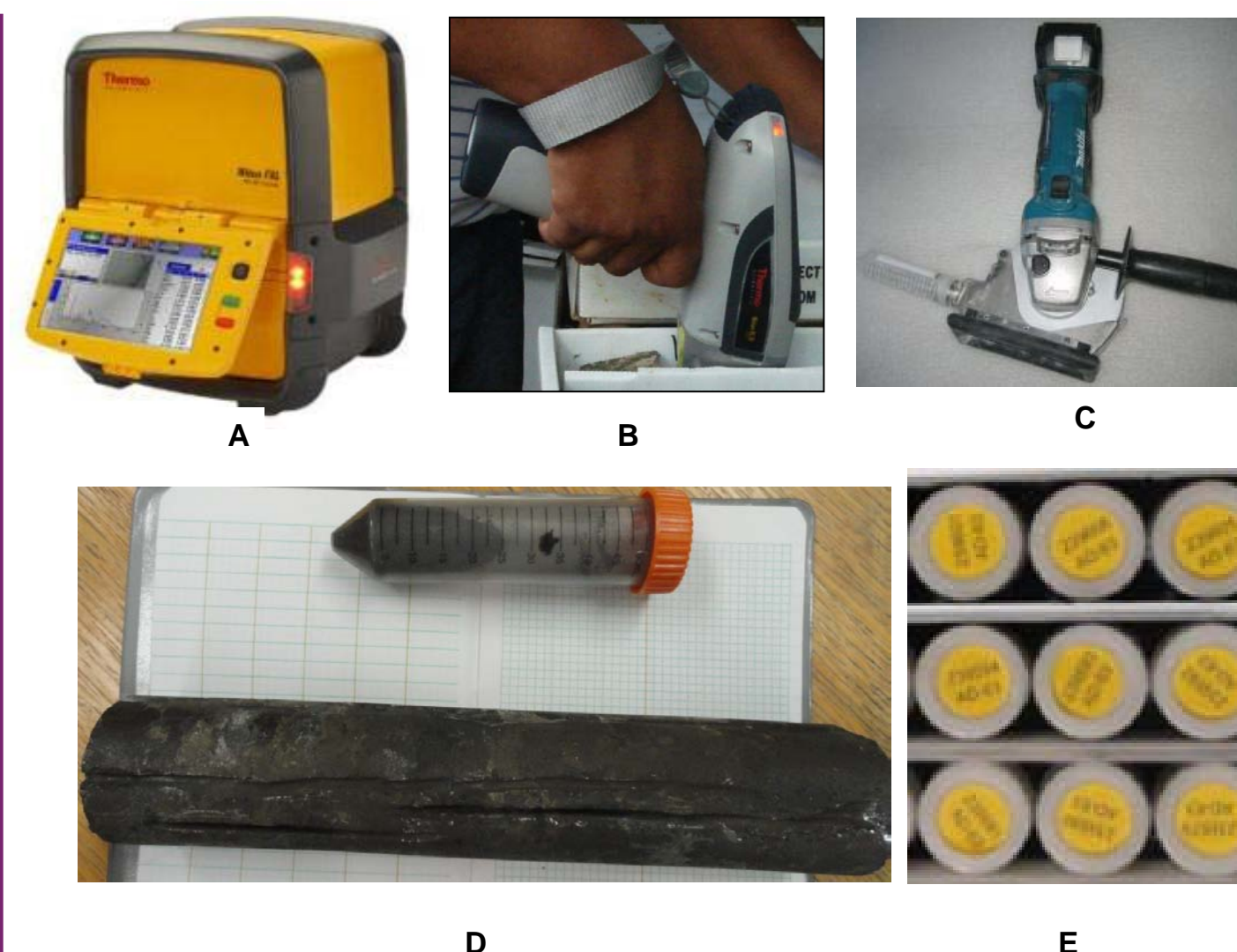


FIGURE 5. A) Niton FXL B) Direct shot (scan) of core samples using Niton XL3t GOLDD+ C) Direct rock/core sampler D) Core cut and sampled by a direct rock/core sampler E) Cupped pulp samples

Pulp samples were collected from drill cores using a direct rock/core sampler.

Results

The study shows high correlation between data from portable XRF and lab methods. Cu correlation between XRF using the Niton XL3t GOLDD+ and ICP method is 0.92 whereas the correlation between XRF using the Niton FXL and AAS method is 0.96 on pulp samples. Similar correlation for Zn assayed by the same instruments yields 0.97 and 0.96 for pulp samples and 72% in direct shot assays. This correlation is 0.80 for Ag and 0.89 for Fe. Lead shows the highest correlation (0.98) among the elements that were analyzed by portable XRF and AAS or ICP methods (Figures 6a and 6b).

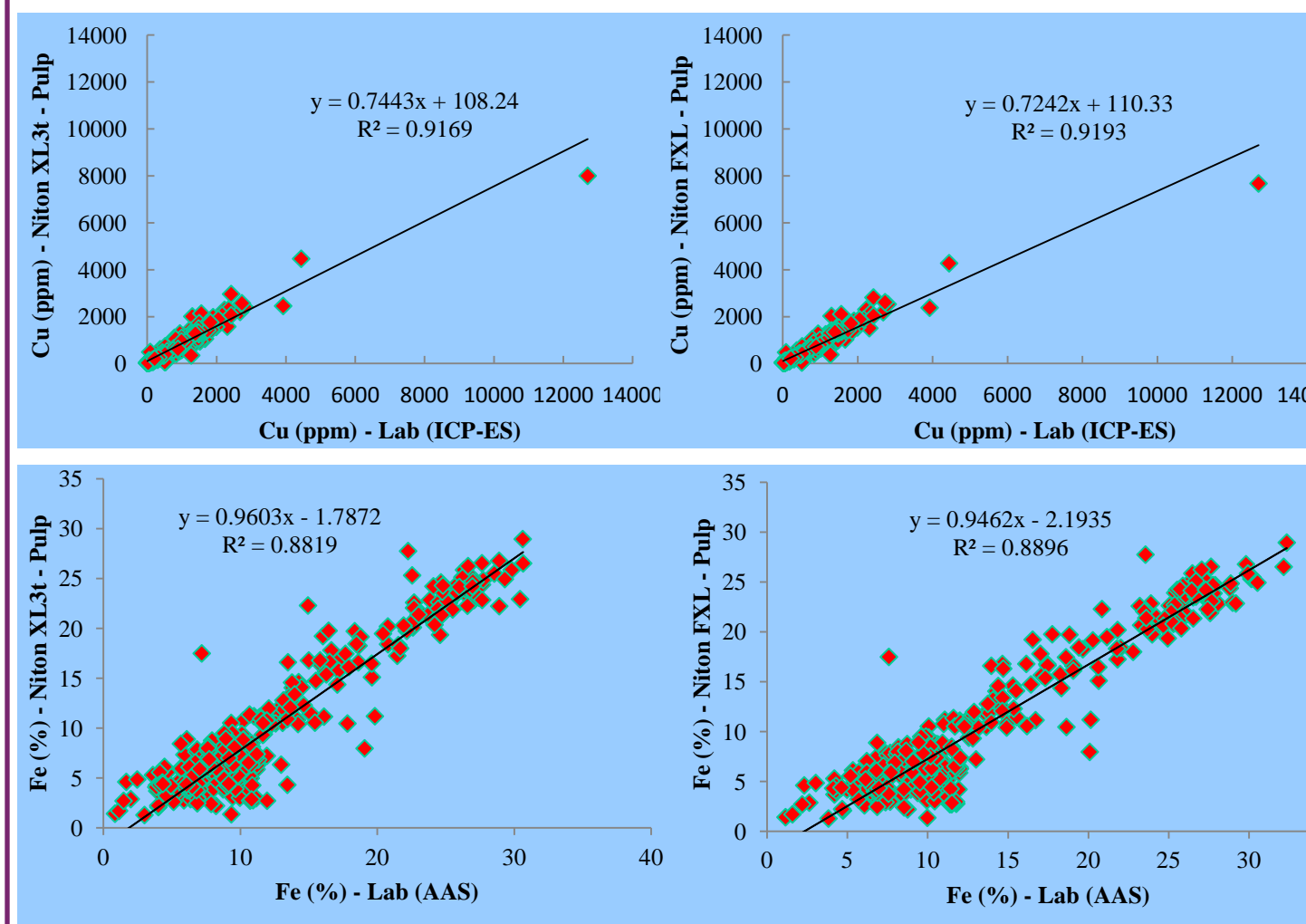


FIGURE 6a. Representative correlation graphs for Cu and Fe analyzed by the Niton FXL, Niton XL3t GOLDD+, and lab (AAS and ICP-ES) methods.

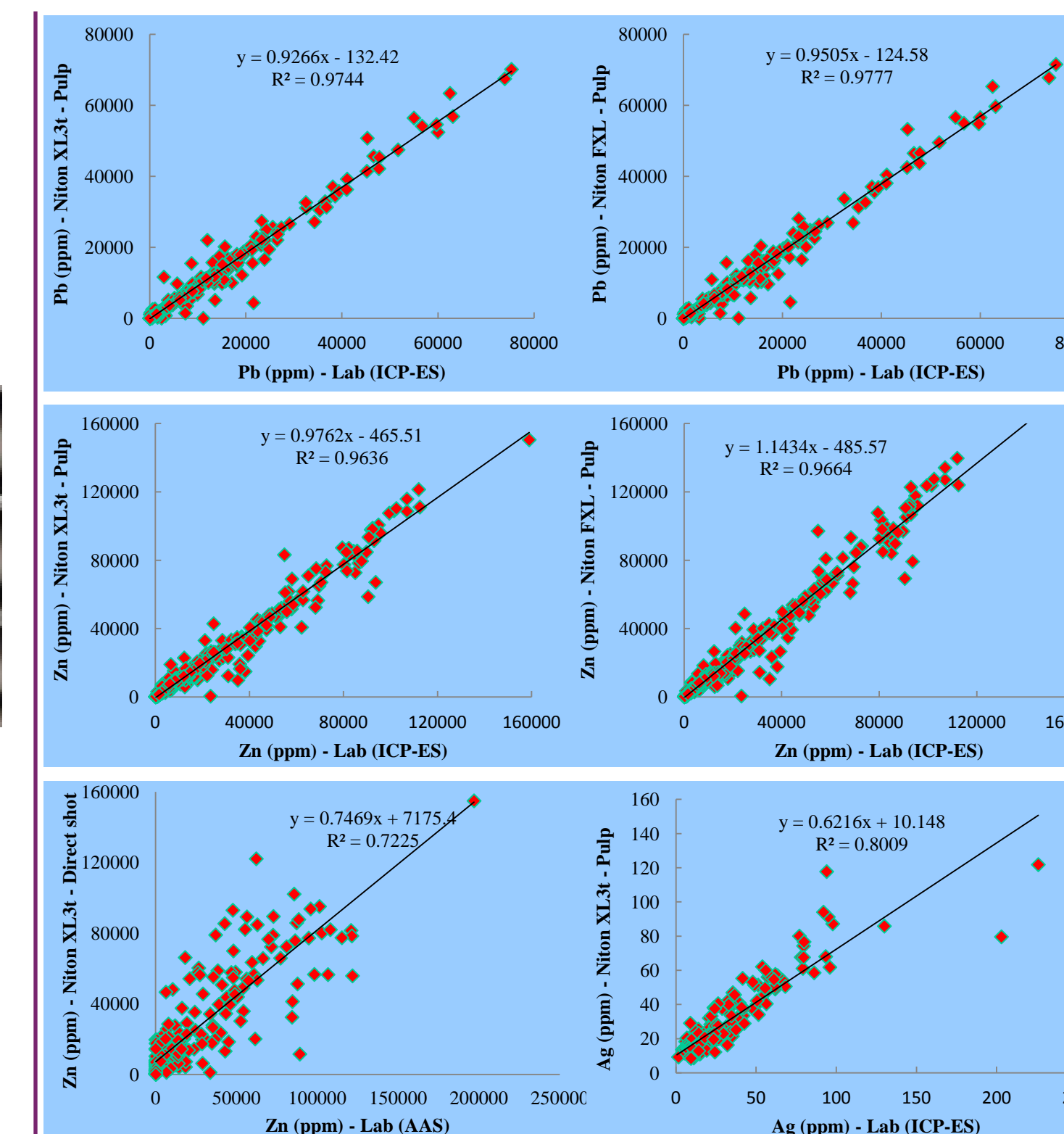


FIGURE 6b. Representative correlation graphs for Pb, Zn, and Ag analyzed by the Niton FXL, Niton XL3t GOLDD+, and lab (AAS and ICP-ES) methods.

In addition, systematic analyses of core samples by these three methods, as well as comparative studies, indicate that geochemical anomalies for metals of interest in this deposit (Zn-Pb-Cu-Ag) as well as light elements such as Al and S can be identified readily in real time using portable XRF in the field (Figures 7a and 7b).

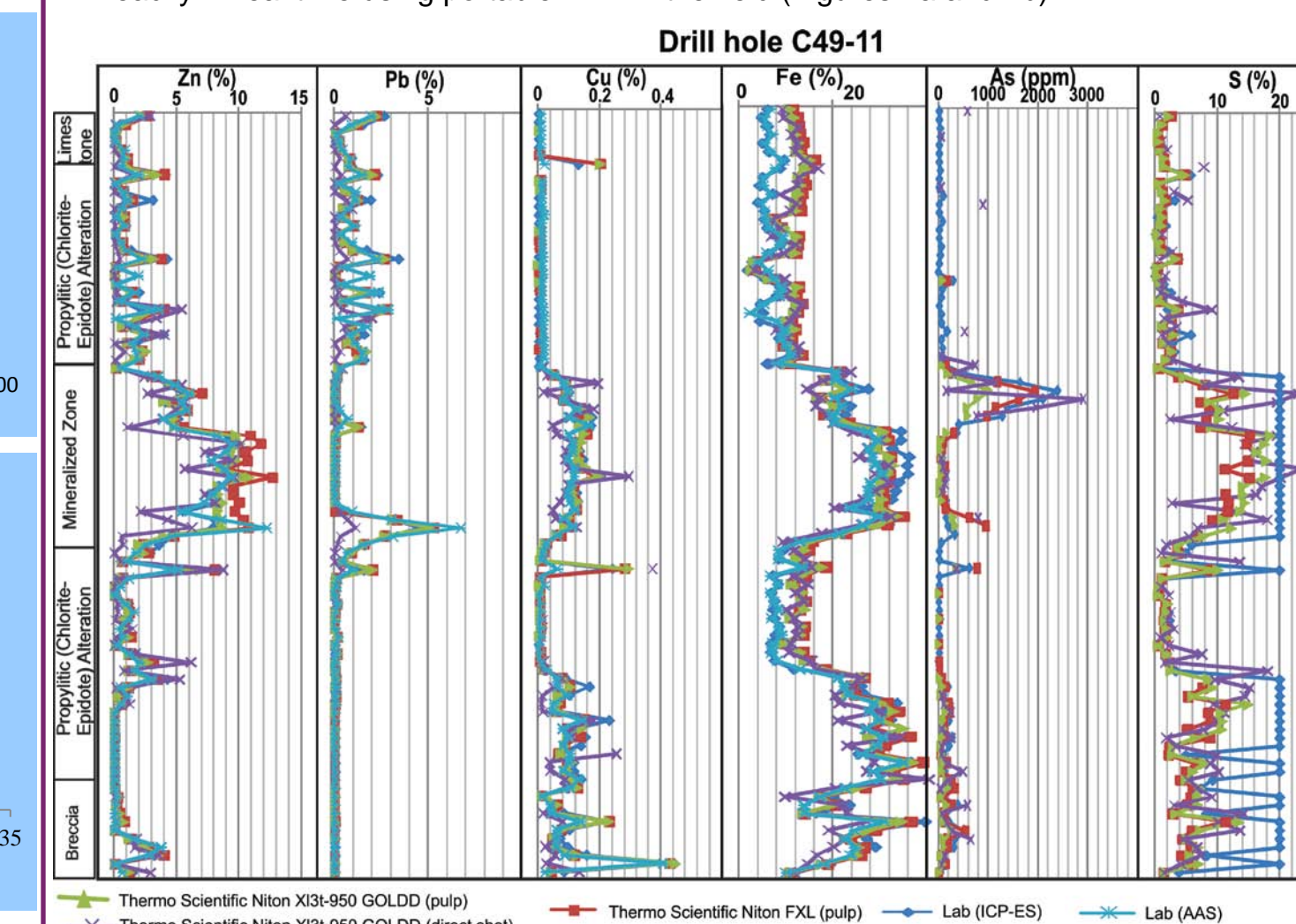


FIGURE 7a. Representative depth-element graphs for drill hole C49-11 showing efficiency of portable XRF in detecting anomalous zones of Zn, Pb, Cu, Fe, As and S.

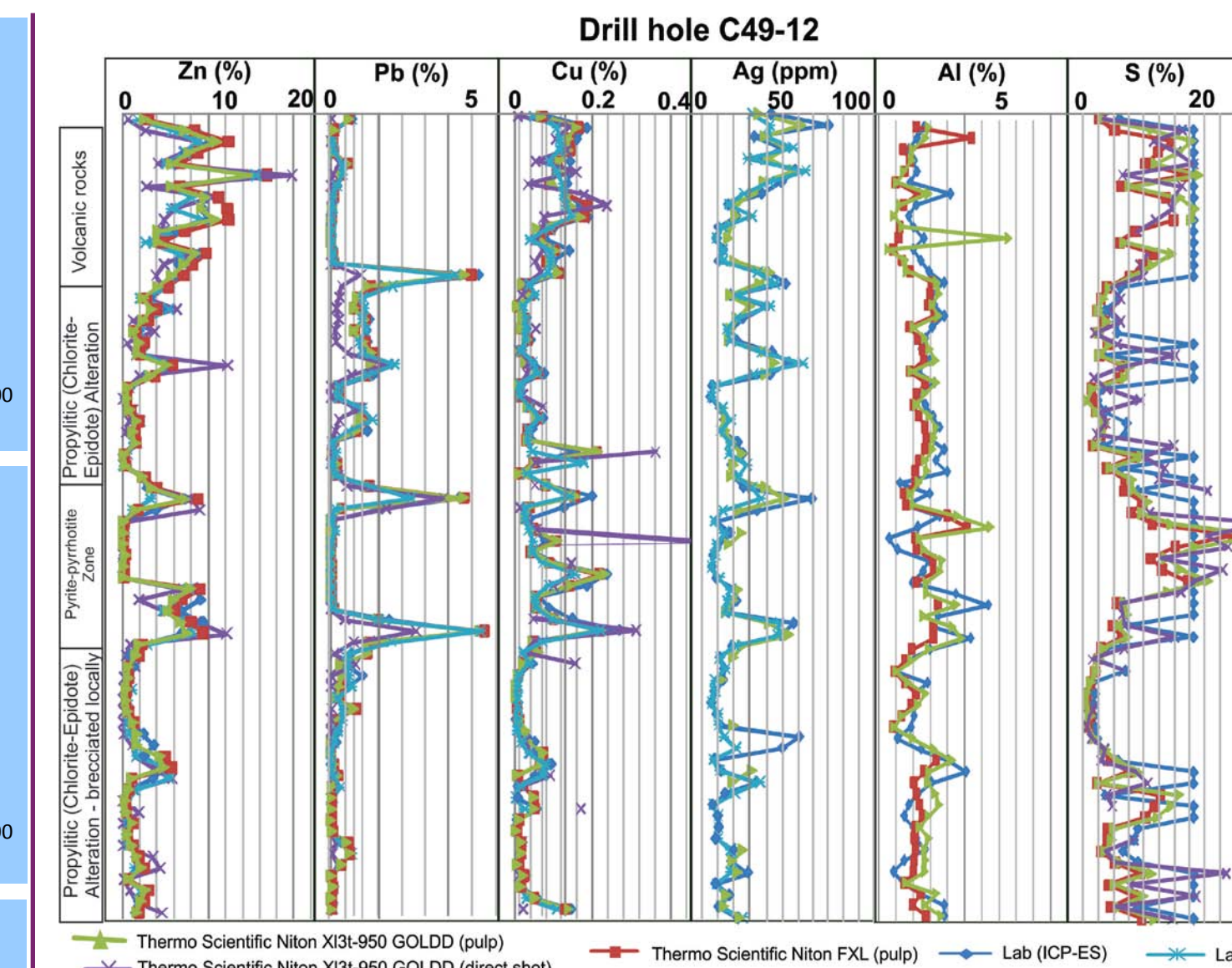


FIGURE 7b. Representative depth-element graphs for drill hole C49-12 showing efficiency of portable XRF in detecting anomalous zones Zn, Pb, Cu, Ag, Al and S.

Conclusion

Portable XRF is used frequently in mining and exploration projects. The study of a large number of geological samples in this project shows that assay results from this method not only have high correlation with lab data, they complement the lab data and provide a fast and effective method for sample sorting, saving money and time. In addition, the geochemical anomalies of base and precious metals as well as light elements (such as S and Al) not only at the surface, but also at depth, can be identified readily in real time onsite using portable XRF. This can be crucial for drilling programs and 3D modeling of ore deposits where the extension of ore mineralization can be traced effectively.

Effects of heterogeneity are significantly reduced by using powdered specimens sampled by a direct rock sampler. As a result, the correlation with lab data increased considerably.

The Francisco I. Madero Zn–Cu–Pb–(Ag) deposit is a good example of the utilization of portable XRF and sample preparations tools in the mining industry. Francisco I. Madero is an active mine with continuous drilling and exploration programs to locate centers of hydrothermal activity that may accommodate large tonnage of ore deposit. The unique geological occurrence of this deposit as a stratabound ore mass between an impermeable shale at the bottom and limestone at the top as well as effective drilling utilizing portable XRF and sample preparation tools can be keys to locating the extension of ore mineralization in this area.

References

Caneta C., Camprubí A., González-Partidac E., Linares C., Alfonsod P., Piñeiro-Fernández F., María Prol-Ledesma R., 2009. Mineral assemblages of the Francisco I. Madero Mexico: Implications for ore deposit genesis. *Ore Geology Reviews*, 35, 423–435.

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