Rate of Iron Monosulfide Formation on IRIS Films

University of Wyoming | Wyoming Research Scholars Program

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PEDOLOGY

INTRODUCTION

How long should IRIS films be deployed to capture FeS formation?

Does FeS formation increase indefinitely on IRIS films?

How can IRIS films be used to estimate FeS formation in the morphology?

The rate and abundance of FeS formation on IRIS films was investigated under strongly reducing soil conditions, in contribution towards providing evidence of anaerobic conditions in soils.

OBJECTIVE: Identify the rate of FeS formation in saturated, sulfur-rich soil.

WE EXPECT to see maximum FeS precipitated on the films two weeks after deployment, after which more Fe^{2+} will become visible.

Reduction of goethite:

$$FeO(OH)\ (s) + e^- + 3H^+\ (aq) \leftrightarrow Fe^{2+}\ (aq) + 2H_2O\ (l)$$

Reduction of sulfate:

$$SO_4^{2-}(aq) + 8e^- + 8H^+\ (aq) \leftrightarrow S_2^-\ (aq) + 4H_2O\ (l)$$

Formation of iron monosulfide:

$$Fe2+\ (aq) + S_2^-\ (aq) \leftrightarrow FeS\ (s)$$

Figure 1. Chemical formulas of Fe^{3+} and sulfate reduction, followed by FeS formation.

METHODS

11 sets (5 reps) of IRIS films were deployed to 50-cm depths in a saturated, gypsum-rich soil during the summer of 2020.

Gypsum = $CaSO_4 \cdot 2H_2O$

Figure 2. IRIS films were randomly installed in a grid. Soil temperature was measured at 25 cm throughout the study.

Morphology

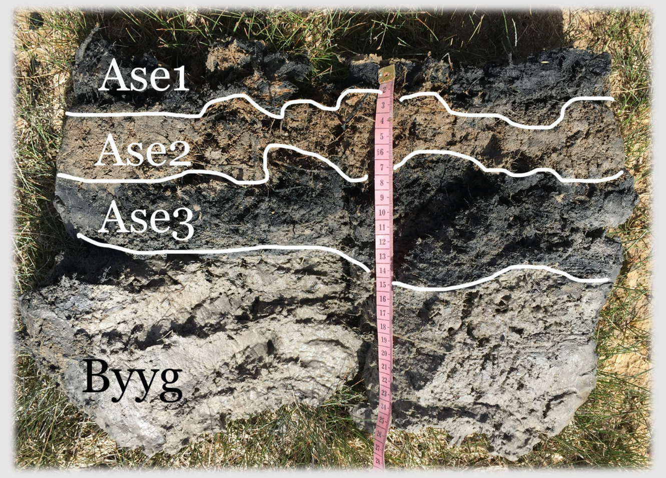


Figure 3. The soil was described using the USDA-NRCS field guidebook (Shoenberger et al., 2012) [3]. Pending lab analyses, the soil is classified as Coarse-silty, gypsic, frigid Leptic Haplogypsids (Soil Survey Staff, Web Soil Survey) [4].

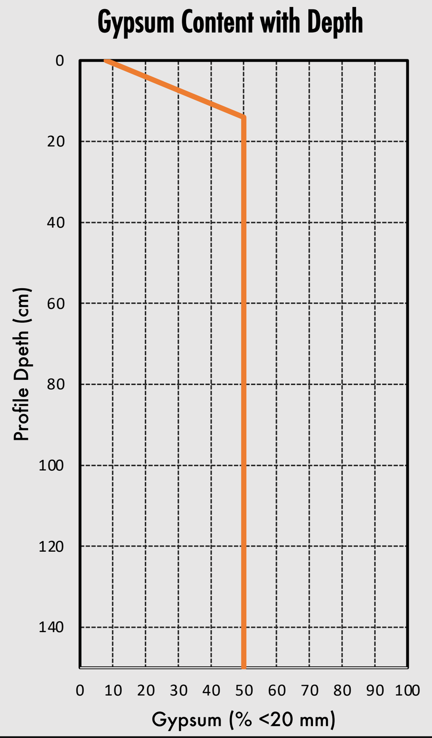


Figure 4. Gypsum content increased with depth. Field estimates cross-referenced with Soil Web data (UC Davis et al 2019) [5].

Film Deployment and Extraction

Five IRIS films were deployed for the following time intervals using the process outlined by Rabenhorst (2018)[1]: 2, 5, 15, & 30 minutes; 1, 6, & 12 hours; and 1, 7, 14, and 30 days.

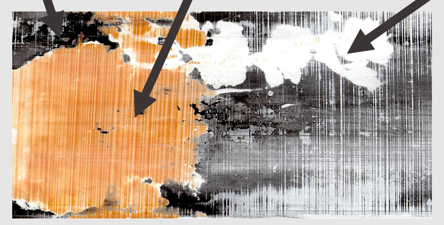
After the allotted time, films were extracted, gently rinsed to remove excess soil, and rapidly scanned on-site to reduce any oxidation due to air exposure.

Using R (R Core Team, 2020) [2], scans of IRIS films were analyzed for percentage of the following:

FeS (black) Fe^{3+} (orange) Fe^{2+} (white)

Figure 5. Soil is extracted using the probe while the IRIS films are deployed.

Figure 6. IRIS films are scanned immediately after extraction to capture FeS formation.



RESULTS & DISCUSSION

Due to strongly-reducing conditions, FeS formation on these IRIS films formed relatively quickly, < 2 minutes (Figure 7).

FeS formation increased from 2 minutes to 12 hours and peaked between 12 hours and 1 day after deployment (Figure 8).

Between 7 and 14 days after deployment, the percentage of iron reduction (white) on the film surpassed coverage by FeS. After 14 days, evidence of FeS formation continues to decline (Figure 8).

In order to capture maximum FeS formation on IRIS films in saturated, gypsum-rich soil, films should be deployed between 12 hours and 1 day (Figures 7 & 8).

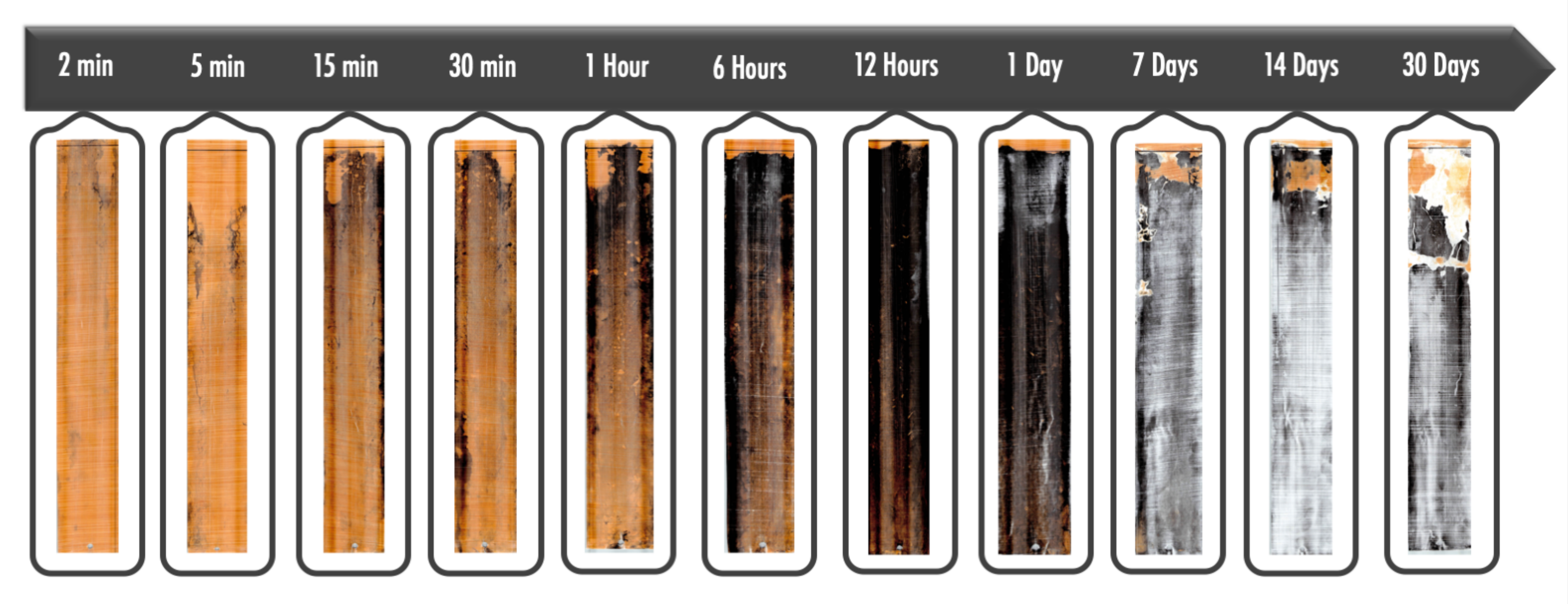


Figure 7. Example IRIS film removed from each time point. Black, FeS formed on the IRIS films installed for the shortest, 2-min duration. White areas (zone of FeS reduction, Fe^{2+}) appeared after 12 hours in situ.

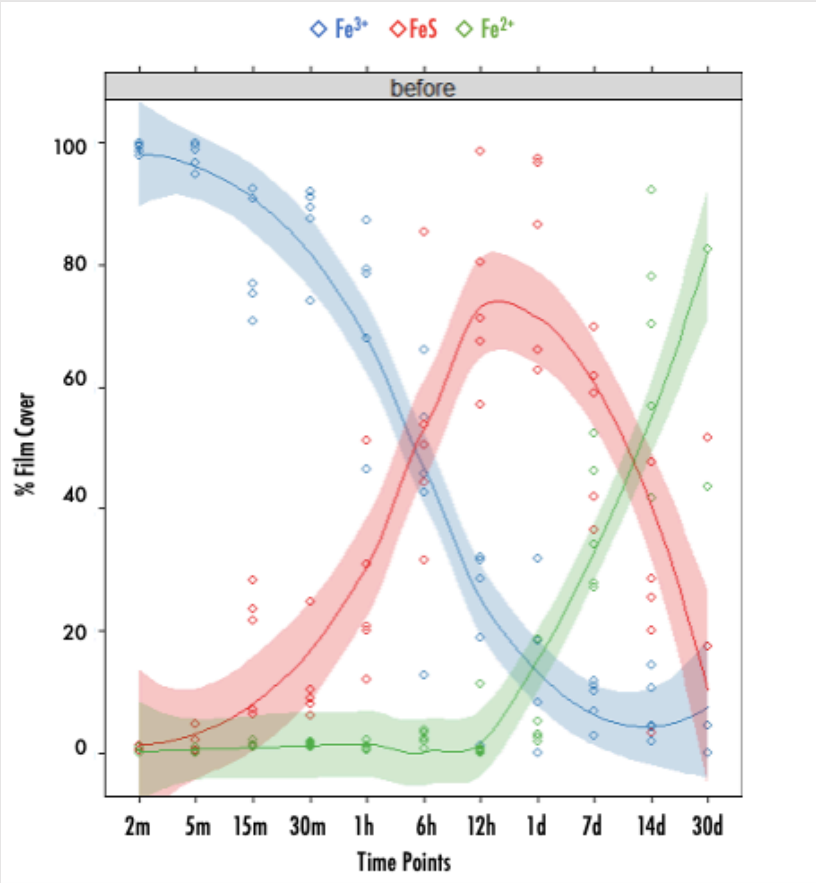


Figure 8. Total amount of FeS formation (black) on the IRIS films increased until the 14-day interval, after which the amount of iron reduction (white) steadily increased.

CONCLUSIONS

FeS can form on IRIS films in under 2 minutes in saturated, reducing conditions.

FeS formation makes up a greater portion of the film, compared to Fe^{2+}, up until 14 days. At which point, the amount of Fe^{2+} surpasses FeS formation.

IRIS films can be accurately used to estimate FeS formation, because of the chemical reaction between Fe^{3+} on the films and sulfate in the soil solution.

REFERENCES

[1] Rabenhorst, M. C. (2018). A System for Making and Deploying Oxide-Coated Plastic Films for Environmental Assessment of Soils. *Soil Science Society of America Journal*, 82(5), 1301–1307.
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