

**Investigating the geochemical model for molybdenum mineralization in the JEB Tailings
Management Facility at McClean Lake, Saskatchewan: An X-ray absorption spectroscopy
study**

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2 **Abstract**

3 The geochemical model for Mo mineralization in the JEB Tailings Management Facility (JEB
4 TMF), operated by AREVA Resources Canada at McClean Lake, Saskatchewan, was
5 investigated using X-ray Absorption Near-Edge Spectroscopy (XANES), an elemental-specific
6 technique that is sensitive to low elemental concentrations. Twenty five samples collected
7 during the 2013 sampling campaign from various locations and depths in the TMF were analyzed
8 by XANES. Mo K-edge XANES analysis indicated that the tailings consisted primarily of Mo⁶⁺
9 species: powellite (CaMoO₄), ferrimolybdite (Fe₂(MoO₄)₃•8H₂O), and molybdate adsorbed on
10 ferrihydrite (Fe(OH)₃ – MoO₄). A minor concentration of a Mo⁴⁺ species in the form of
11 molybdenite (MoS₂) was also present. Changes in the Mo mineralization over time were
12 inferred by comparing the relative amounts of the Mo species in the tailings to the independently
13 measured aqueous Mo pore water concentration. It was found that ferrimolybdite and molybdate
14 adsorbed on ferrihydrite initially dissolves in the TMF and precipitates as powellite.

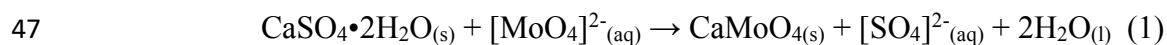
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16 Introduction

17 The JEB Tailings Management Facility (JEB TMF) plays a central role in reducing the
18 environmental impact of AREVA Resources Canada's (AREVA) uranium ore mining operations
19 in Northern Saskatchewan. The geochemistry of the tailings management system is designed to
20 reduce the migration of water-soluble elements that co-mineralize with U ore (i.e. As, Ni, Mo,
21 and Se) by promoting the formation of mineral species.¹ However, when initially added to the
22 tailings, the concentration of the solutes are generally out of equilibrium with the desired
23 minerals, requiring a long period of time to reach their respective mineralogical end point.¹ As
24 such, predicting and controlling the long-term mineralization in the TMF is essential to prevent
25 pollutant elements from contaminating the surrounding environment.

26 AREVA has been investigating the long-term mineralization of elements such as As and
27 Ni in the TMF for many years.²⁻⁴ $As^{5+}_{(aq)}$ concentrations are well controlled (< 1 mg/L) because
28 of the co-precipitation of $Fe^{3+}_{(aq)}$ and $As^{5+}_{(aq)}$ as poorly crystalline scorodite ($FeAsO_4 \cdot 8H_2O$)
29 because of the excess Fe in the TMF.²⁻⁴ Likewise, $Ni^{2+}_{(aq)}$ concentrations are controlled by the
30 adsorption of $Ni^{2+}_{(aq)}$ on ferrihydrite ($Fe(OH)_3$).³ There has been comparatively fewer studies of
31 how Mo mineralization in the TMF. The primary Mo-bearing mineral in the ore is molybdenite
32 (MoS_2),⁵ which is oxidized to water-soluble molybdate ($[MoO_4]^{2-}_{(aq)}$) when leaching (pH ~ 1) the
33 uranium ore at the JEB uranium mill.⁶ During the tailings preparation process, the waste solid
34 and solution are mixed with ferric sulfate ($Fe_2(SO_4)_3$). Although intended to control the release
35 of arsenic in the TMF, $Fe^{3+}_{(aq)}$ will also co-precipitate with $[MoO_4]^{2-}_{(aq)}$ to form ferrimolybdate
36 ($Fe_2(MoO_4)_3 \cdot 8H_2O$) and molybdate adsorbed on ferrihydrite ($Fe(OH)_3 - MoO_4$) as the pH is
37 raised to 4.^{1,6} The pH is then raised to 7-8 prior to adding the tailings slurry to the TMF.
38 $[MoO_4]^{2-}_{(aq)}$ is predicted to be present in the TMF because ferrimolybdate and molybdate

39 adsorbed on ferrihydrite are soluble under the near-neutral conditions of the TMF.
40 Coincidentally, the TMF is saturated with gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) because of the addition of
41 sulfuric acid (H_2SO_4) and lime (CaO) during the milling process, resulting in high concentrations
42 of $\text{Ca}^{2+}_{(\text{aq})}$ (500 mg/L) and $[\text{SO}_4]^{2-}_{(\text{aq})}$ (2800 mg/L) throughout the pore water of the TMF.
43 Thermodynamic calculations predict that the strongly oxidizing conditions of the TMF, with an
44 Eh of +290 mV and a dissolved O^{2-} concentration of 5-7 mg/L, would promote the co-
45 precipitation of $\text{Ca}^{2+}_{(\text{aq})}$ and $[\text{MoO}_4]^{2-}_{(\text{aq})}$ as powellite (CaMoO_4).⁶ The overall geochemical
46 model for the formation of powellite can be described by the following reaction:



48 X-ray absorption near-edge spectroscopy (XANES) and X-ray diffraction (XRD) analysis
49 of tailings samples from the JEB TMF collected during the 2008 sampling campaign confirmed
50 the presence of powellite in the TMF.⁷ However, it was not possible to determine if the
51 predicted mineralogical end-point of powellite is correct as only six samples were analysed.
52 Powellite was also observed in a related XANES study on the Mo speciation in the Deilmann
53 Tailings Management Facility (DTMF) operated by the Cameco Corporation.⁵ Given the
54 environmental implications, it is important to confirm that the geochemical model for controlling
55 the release of Mo in JEB TMF is correct. XANES was used to identify and quantify the
56 concentrations of the various Mo species in the TMF by analyzing tailings samples collected
57 during the 2013 sampling campaign. XANES is a powerful analytical technique for studying
58 environmental samples because it can be used to identify low concentrations of chemical species
59 present in heterogeneous samples. Twenty five samples were studied, representative of the total
60 depth of the tailings from two bore holes in the TMF. The sampling depth itself correlates with
61 the age of the tailings due to the settled nature of the TMF. Therefore, the mineralization of Mo

62 in the TMF can be inferred by comparing the concentration of the various Mo species in the
63 tailings solids to the concentration of aqueous Mo in the tailings pore water. This study verified
64 the existing geochemical model and confirmed that powellite controls the aqueous Mo pore
65 water concentration in the TMF.

66 **Experimental**

67 **Tailings sample description and analysis**

68 The twenty-five samples analysed in this study were collected from two bore hole
69 locations during the 2013 sampling campaign of the JEB TMF. Fourteen of the samples were
70 collected from a bore hole located at the centre of the TMF (TMF13-01) while eleven of the
71 samples were collected from a periphery bore hole (TMF13-03) located 55 m from the central
72 bore hole. The tailings are placed in the TMF using a floating barge and tremie piping system.
73 While the design minimizes particle size segregation at the point of placement, it does not
74 eliminate it. Consequently, with respect to particle size distribution, the tailings solids in the
75 TMF are not homogenous. The central bore hole possesses a significantly coarser particle size
76 distribution than the peripheral bore hole. Tailings solids from the central bore hole can contain
77 large grains of primary Mo mineralization (molybdenite; MoS_2) that were too large to be fully
78 oxidized in the uranium mill process.

79 The samples were collected in approximately 3 m intervals using a Gregory-type piston
80 sampler by engineers from AREVA Resources Canada's Safety, Health, Environment, and
81 Quality (SHEQ) department. Material at the end of the sampler was discarded due to exposure
82 to air. The pore water was collected by hydraulically pressing the samples and analyzed using
83 inductively coupled plasma-mass spectrometry (ICP-MS) analysis to determine the aqueous Mo
84 pore water concentration. The Mo pore water concentration was found to vary from 1.25 – 44.20

85 mg/L. Solid tailings samples were nitrogen-purged, vacuumed-sealed, and stored in a freezer
86 (~5 °C) to prevent oxidation. Once transported to the University of Saskatchewan, samples were
87 stored in a N₂-filled glove box. Samples were not exposed to air until the XANES measurements
88 were performed, which was approximately one year after the samples were collected from the
89 TMF. A complete sample list, including sample elevation and aqueous Mo pore water
90 concentration, is found in Supporting Information (Table S1). The concentrations of select
91 elements in the tailings solids, as determined by ICP-MS, are also found in Supporting
92 Information (Table S2).

93 **Mo K-edge XANES**

94 All Mo K-edge XANES measurements were performed using the Hard X-ray
95 MicroAnalysis (HXMA) beamline (06ID-1) at the Canadian Light Source.⁸ Samples were
96 packed into 2.33 mm thick rectangular Teflon holders, which were sealed with two layers of
97 Kapton tape. Samples were positioned in front of the X-ray beam at a 45° angle. Spectra were
98 collected from 19800–20650 eV with a step size of 0.3 eV near the Mo K-edge. The energy
99 range was selected using a silicon (220) crystal monochromator that provided a monochromatic
100 flux on the order 10¹² photons/sec with a resolution of 2 eV at 20 keV, which is less than the
101 natural linewidth of the Mo K-edge (4.52 eV).⁹ All spectra were measured in partial
102 fluorescence yield (PFY) mode using a 32 element Ge detector and calibrated against Mo metal,
103 with the maximum of the first derivative of the Mo K-edge set to 20,000 eV.¹⁰ Multiple scans
104 were collected for each spectrum. The samples were observed to not undergo any X-ray beam-
105 induced reduction as there was no change in the spectra between successive scans.

106 All XANES spectra were analysed using the Athena software program.¹⁰ A quantitative
107 analysis of the spectra was conducted by performing a principal component analysis (PCA)

108 followed by a linear combination fitting (LCF) of the spectra. The energy range used for the
109 PCA and LCF analysis was 19990–20075 eV. The standards used in the LCF analysis (MoS₂,
110 MoO₂, MoO₃, H₂MoO₄, CaMoO₄, α -NiMoO₄, α -FeMoO₄, Fe₂(MoO₄)₃•8H₂O, Fe(OH)₃ – MoO₄.)
111 were the same as those used in our previous Mo K-edge XANES study.⁷ An energy shift was
112 not applied during the LCF as the standards were calibrated against the same reference (Mo
113 metal) as the tailings samples.

114 **Results and Discussion**

115 **Mo K-edge XANES spectra**

116 The Mo K-edge XANES spectra of representative tailings samples from the central and
117 peripheral bore holes are shown in Figure 1. The complete set of Mo K-edge XANES spectra
118 from the tailings samples studied can be found in the Supporting Information (Figures S1 – S2).
119 The Mo K-edge corresponds to the dipole-allowed ($\Delta l = \pm 1$) transition of the 1s electron into
120 unoccupied Mo 5p states. In general, the absorption edge energy is sensitive to the oxidation
121 state of Mo, as well as bond covalency.^{7,11} A low intensity pre-edge feature (19990–20010 eV)
122 is also observed in the Mo K-edge, which corresponds to a dipole-forbidden ($\Delta l = \pm 2$) transition
123 of a 1s electron into unoccupied Mo 4d states. The intensity of the pre-edge is influenced by the
124 local coordination environment of the absorbing Mo atom.¹¹

125 The majority of the Mo K-edge XANES spectra from the tailings samples have similar
126 lineshapes. The Mo K-edge absorption-edge energy (and general lineshape) of the tailings
127 samples were more similar to that of MoO₃ (Mo⁶⁺) than MoO₂ or MoS₂ (Mo⁴⁺), as shown in
128 Figure 2. The Mo K-edge lineshape of the tailings samples are also different than that of
129 tetrathiomolybdate ([MoS₄]²⁻; Mo⁶⁺),¹² indicating that the tailings samples consist mostly of
130 Mo⁶⁺ oxides, which is in agreement with a previous report.⁷ Broadening of the near-edge region

131 of spectra from samples collected from the central bore hole (Figure 1a) was observed, which
132 may be due to the presence of Mo⁴⁺.^{13,14}

133 **Principle Component Analysis**

134 Visual inspection of the Mo K-edge XANES spectra suggests the tailings consist of
135 multiple Mo species. Advanced analysis techniques are required to identify and quantify the
136 Mo-bearing species in the TMF. Principle component analysis (PCA) was first used to
137 determine the number of Mo species present in the 2013 tailings samples. The PCA calculation
138 decomposes a series of spectra into a set of components that describes the variation in the data
139 set.^{15,16} Full details of the PCA analysis can be found elsewhere.⁷ Results of the PCA analysis
140 for samples from each bore hole can be found in the Supporting Information (Figure S3). The
141 IND function, an empirical function used to differentiate between major and minor components
142 in a PCA, was calculated for each bore hole to determine the minimum number of components in
143 each series.^{17,18} It is generally accepted that the minimum number of components is given when
144 the IND function is minimized.^{17,18} The IND values are generally small after the first
145 component, which may be due to variations in the number of species present in each sample.
146 The similar IND values obtained for 2 – 4 components suggests a maximum of four components
147 are present in the tailings samples. This can be observed when reconstructing the spectra from
148 tailings samples TMF13-01-SA23 (see Figure S4 in the Supporting Information), where a slight
149 improvement is observed (particularly in the pre-edge region) when reconstructing the spectrum
150 with four components.

151 **Linear Combination Fitting Analysis**

152 Linear combination fitting (LCF) analysis was employed to identify the Mo species
153 present in the tailings samples. Each normalized Mo K-edge spectrum was fitted to the linear

154 combination of weighted standard spectra. The Mo K-edge XANES spectra from the Mo-
155 bearing standards used in the LCF analysis are plotted in Figure S5 in the Supporting
156 Information. All of the Mo⁶⁺ standards consist of MoO₄ tetrahedral units; however, the Mo K-
157 edge lineshape of these standards are quite different in the near-edge region (20010–20040 eV)
158 due to effects from the presence of different next-nearest neighbours (i.e. Ca, Fe, etc). The
159 coefficients calculated in the LCF, which correspond to the concentration of each Mo species
160 relative to the total amount of Mo in the tailings, were allowed to vary between 0 and 1 with the
161 total sum of the coefficients constrained to 1. Several different fitting models using different
162 combinations of standards were tested. Best fits were determined by calculating the goodness-
163 of-fit parameters (R-value and χ^2). Generally, the fit with the smallest R-value and χ^2 value was
164 considered the best. Decreasing the fitting range from 19990–20075 eV to 19990–20040 eV had
165 no effect on the calculated concentrations, indicating that there are sufficient details in the pre-
166 and near-edge regions to distinguish between the different Mo species in the tailings samples.
167 Results of the best fits are tabulated in Table 1 and representative fitted spectra are shown in
168 Figure 3. The fitted spectra from all other tailings samples are presented in Figures S6 – S9 in
169 the Supporting Information.

170 The best fits were obtained when fitting the spectra to ferrimolybdite
171 (Fe₂(MoO₄)₃*8H₂O), powellite (CaMoO₄), molybdate adsorbed on ferrihydrite (Fe(OH)₃ –
172 MoO₄), and molybdenite (MoS₂). The concentration of molybdenite is small in most tailings
173 samples (less than 10 at%). However, including molybdenite significantly improves the fitting
174 of the near-edge region and the goodness-of-fit (see Figure S10 and Table S3 in Supporting
175 Information). This suggests that molybdenite is an essential component in the fittings. Because
176 of the oxic conditions of the TMF, the likely source of molybdenite is unprocessed ore that was

177 not fully oxidized during the uranium milling process. Although molybdenite was not found in
178 our previous XANES study of samples collected in 2008, it does not mean that molybdenite was
179 not present in the TMF during this period.⁷

180 It should be noted that slightly better fits were obtained when using molybdic acid
181 (H_2MoO_4) rather than powellite. However, molybdic acid is soluble at the pH of the TMF (~7-
182 8).¹⁹ As such, molybdic acid was excluded from the fittings. The overfitting of the broad peak
183 near 20040-20060 eV is likely due to multiple scattering resonance (MSR) peaks contributing to
184 the intensity of this feature. MSR is a low-energy extended X-ray absorption fine structure
185 (EXAFS) phenomenon that is highly dependent on crystal structure and crystallinity.²⁰ The
186 intensity of MSR contributions decreases with decreasing crystallinity, and the overfitting
187 observed in this region is indicative of the poor crystallinity of these materials. This observation
188 is consistent with our previous study of the 2008 tailings samples.⁷

189 **Comparison of the Mo speciation in the 2008 and 2013 tailings samples.**

190 The Mo K-edge XANES spectra of the 2008 and 2013 tailings samples collected at the
191 same depth were noticeably different (see Figure S11 in the Supporting Information). This
192 suggests that changes in the Mo speciation in the tailings have occurred over the five year period
193 between sampling campaigns. Comparing the relative amounts of Mo^{6+} species in tailings
194 samples collected at different dates from the same elevation and bore hole can provide some
195 indication as to which Mo^{6+} species are stable in the TMF over long periods of time. In 2008:
196 the tailings deposited at approximately 411 mASL (meters above sea level) were less than a year
197 old; at 398 mASL the tailings were approximately five years old; and at 371 mASL the tailings
198 were approximately ten years old. It follows for the 2013 samples that the tailings sampled at
199 411, 398, and 371 mASL are approximately five, ten, and fifteen years old, respectively. Figure

200 4 compares the distribution of Mo⁶⁺ species from the peripheral bore hole in 2008 and 2013.
201 Near the surface of the TMF (~411 mASL), the relative amount of powellite increased from 10
202 at% (2008 tailings sample) to 25 at% (2013 tailings sample). In contrast, the relative amounts of
203 ferrimolybdate and molybdate adsorbed on ferrihydrite decreased over the same five year period,
204 suggesting that powellite is more stable in the TMF over time. Smaller changes in the amount of
205 powellite present were observed at lower elevations. It is apparent that relatively rapid changes
206 in the Mo mineralogy occurs within the first five years of placement in the TMF. Following this,
207 the precipitation of powellite appears to slow at lower elevations.

208 **Depth analysis of the TMF**

209 Powellite precipitates over time in the TMF, which is consistent with the predicted
210 geochemical model (equation 1). This can be confirmed by comparing the relative amounts of
211 solid Mo species in the TMF to the aqueous Mo pore water concentration. The aqueous Mo pore
212 water concentration is plotted against the sample elevation for the central and peripheral bore
213 holes in Figure 5. In general, higher aqueous Mo pore water concentrations are observed at
214 elevations above 400 mASL (i.e. closer to the surface of the TMF) and sharply decrease at lower
215 elevations. This suggests that, within the older tailings, a solid Mo mineral phase forms that
216 results in a decrease of the aqueous Mo pore water concentration. It should be noted that this
217 effect is more evident in the peripheral bore hole compared to the central bore hole.

218 As shown in Figure 5a, a sharp increase in the relative amount of powellite in the tailings
219 is observed at elevations below ~400 mASL, particularly in the peripheral bore hole. The
220 aqueous Mo pore water concentration remains low in tailings containing relatively high powellite
221 content. The increase in the relative amount of powellite at lower elevations confirms that
222 aqueous Mo precipitates to form powellite over time. The opposite trend is observed in the

223 combined relative amounts of ferrimolybdate and molybdate adsorbed on ferrihydrite (Figure
224 5b). Elevated concentrations of Mo in the pore water of the upper tailings are consistent with the
225 dissolution of ferrimolybdate and molybdate adsorbed on ferrihydrite. The dissolution and re-
226 precipitation of Mo as powellite confirms that the existing Mo geochemical model of the TMF is
227 correct and that powellite controls the long term stability of Mo in the pore water.

228 The effects of particle size of the tailings can be observed by comparing Mo speciation of
229 the tailings from the central bore hole compared to the peripheral bore hole. A larger amount of
230 molybdenite (~30 at%) is observed in three samples (TMF13-01-SA21, TMF13-01-SA22,
231 TMF13-01-SA23) collected from the central bore hole at 370 – 380 mASL. As shown in Figure
232 6a, the increase in molybdenite content correlates with a small increase in the aqueous Mo pore
233 water concentration at roughly the same elevation in the central bore hole. There is no
234 significant change in the amount of molybdenite or aqueous Mo pore water concentration of the
235 peripheral bore hole with increasing depth (Figure 6b). Under the conditions of the TMF,
236 molybdenite should oxidize. Therefore, the aqueous Mo pore water concentration should be
237 higher in regions of the TMF containing large (~30 at%) amounts of molybdenite, as is
238 illustrated in Figure 6a. Note that there was no correlation between the aqueous Mo pore water
239 concentration and the amount of molybdenite at elevations above 400 mALS. This is likely due
240 to the dissolution of ferrimolybdate and molybdate adsorbed on ferrihydrite at higher elevations,
241 increasing the levels of Mo in the pore water and masking this more minor effect.

242 Overall, these results show that the aqueous Mo pore water concentration decreases as a
243 direct result of the precipitation of powellite.

244

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256 contributions.

257 **Associated Information**

258 Additional details of the Mo content of the tailings samples, results of the PCA of the
259 tailings samples, fitted Mo K-edge spectra from additional tailings samples, and Mo K-edge
260 XANES spectra comparing the 2008 and 2013 tailings samples are reported. This material is
261 available free of charge via the Internet at <http://pubs.acs.org>.

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312

313 **Figure Captions**

314 **Figure 1.** Representative Mo K-edge XANES spectra of tailings samples collected from the a)
315 central (TMF13-01) and b) peripheral (TMF13-03) bore holes.

316 **Figure 2.** The Mo K-edge XANES spectrum of tailings sample TMF13-01-SA23. The
317 absorption-edge energy is similar to that of MoO₃, suggesting a large concentration of Mo⁶⁺.

318 **Figure 3.** The fitted Mo K-edge XANES spectra of tailings samples a) TMF13-01-SA01, b)
319 TMF13-01-SA22, c) TMF13-03-SA02, and d) TMF13-03-SA21. The linear combination fit of
320 the spectrum is shown in red and the residual is shown in green. The weighted spectra of the
321 standards used to fit the spectra are also shown.

322 **Figure 4.** A comparison of the distribution of Mo⁶⁺ species (powellite, ferrimolybdate, and
323 molybdate adsorbed on ferrihydrite) from tailings samples collected from the peripheral bore
324 hole in 2008 and 2013. Note that a larger amount of powellite was observed in the 2013 tailings
325 samples, particularly at lower elevations.

326 **Figure 5.** The aqueous Mo pore water concentration (black line; ●) compared to the relative
327 amounts of solid a) powellite (red line; ■) and b) ferrimolybdate and molybdate adsorbed on
328 ferrihydrite (blue line; ▲) plotted against the sample depth of the central bore hole (left side) and
329 peripheral bore hole (right side). Errors in the Mo pore water concentrations are estimated to be
330 15% for concentrations greater than 1 mg/L. Where not apparent, the error bars are smaller than
331 the symbols.

332 **Figure 6.** The aqueous Mo pore water concentration (black line; ●) compared to the relative
333 amount of solid molybdenite (green line; ◆) plotted against the sample depth of the a) central
334 bore hole (TMF13-01) and b) peripheral bore hole (TMF13-03). The plots highlight the changes
335 in the aqueous Mo pore water concentration and sediment molybdenite at elevations below 400

336 m (i.e. older tailing samples). Errors in the Mo pore water concentrations are estimated to be
337 15% for concentrations greater than 1 mg/L. Where not apparent, the error bars are smaller than
338 the symbols.

Tables and Figures

Table 1. Results of the LCF analysis of the Mo K-edge XANES spectra from the tailings samples. Calculated errors are shown in brackets.

Sample	CaMoO ₄ (at%)	Fe(OH) ₃ -MoO ₄ (at%)	Fe ₂ (MoO ₄) ₃ (at%)	MoS ₂ (at%)	R-factor	χ^2
TMF13-01-SA01	8(3)	43(2)	43(3)	7(5)	0.00276	0.0592
TMF13-01-SA03	0(3)	55(3)	36(3)	9(5)	0.00306	0.0790
TMF13-01-SA04	18(3)	17(3)	41(4)	24(6)	0.00400	0.0932
TMF13-01-SA06	7(4)	63(3)	20(4)	10(6)	0.00415	0.115
TMF13-01-SA11	41(2)	30(2)	11(3)	19(4)	0.00181	0.0470
TMF13-01-SA12	38(2)	37(2)	17.4(6)	8(4)	0.00230	0.0519
TMF13-01-SA14	20(3)	55(2)	7(3)	17(5)	0.00304	0.0747
TMF13-01-SA19	30(2)	41(2)	13(3)	16(4)	0.00185	0.0466
TMF13-01-SA20	16(3)	45(3)	28(4)	11(6)	0.00400	0.102
TMF13-01-SA21	12(4)	54(5)	5(3)	29.7(9)	0.00450	0.113
TMF13-01-SA22	27(2)	42(2)	3(3)	28(4)	0.00196	0.0489
TMF13-01-SA23	10(3)	59(3)	4(3)	27(5)	0.00306	0.0778
TMF13-01-SA24	30(3)	24(3)	31(3)	16(5)	0.00319	0.0855
TMF13-01-SA25	19(3)	42(3)	25(4)	14(6)	0.00417	0.102
TMF13-03-SA02	5(3)	51(3)	36(3)	8(5)	0.00281	0.0742
TMF13-03-SA04	4(3)	26(3)	60(4)	10(6)	0.00391	0.0974
TMF13-03-SA06	25(2)	43(2)	25(3)	9(4)	0.00195	0.0508
TMF13-03-SA07	6(1)	51(1)	37(2)	6(3)	0.000993	0.0247
TMF13-03-SA11		85(4)		15(9)	0.00871	0.239
TMF13-03-SA12	44(3)	32(3)	16(3)	8(5)	0.00269	0.0732
TMF13-03-SA14	31(3)	19(3)	38(3)	13(5)	0.00335	0.0866
TMF13-03-SA15	39(3)	20(2)	26(3)	14(5)	0.00282	0.0709
TMF13-03-SA19	40(3)	30(2)	23(3)	7(4)	0.00214	0.0565
TMF13-03-SA21	45(3)	19(3)	22(4)	15(6)	0.00406	0.103
TMF13-03-SA22	38(3)	28(3)	26(3)	9(5)	0.00286	0.0750

Figure 1

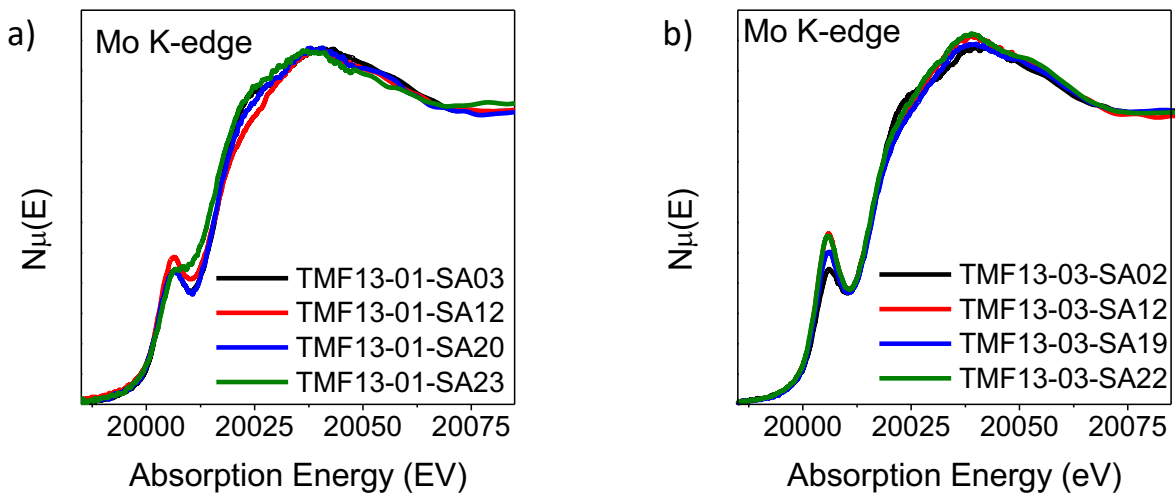


Figure 2

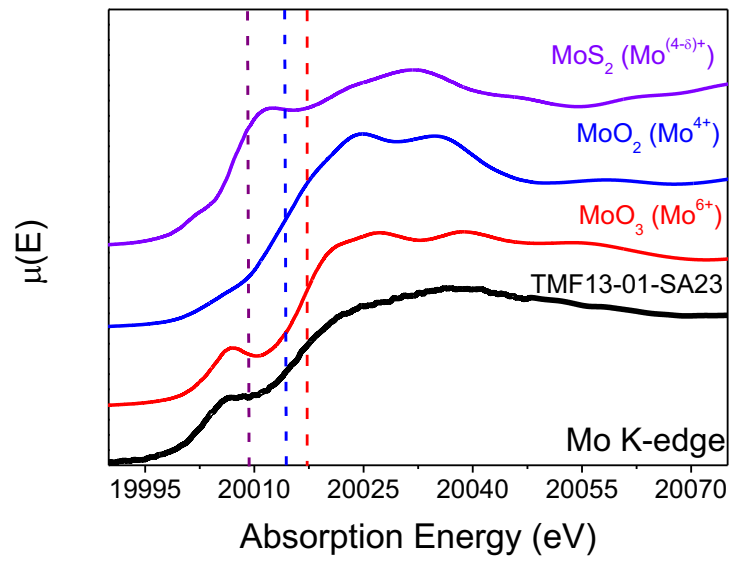


Figure 3

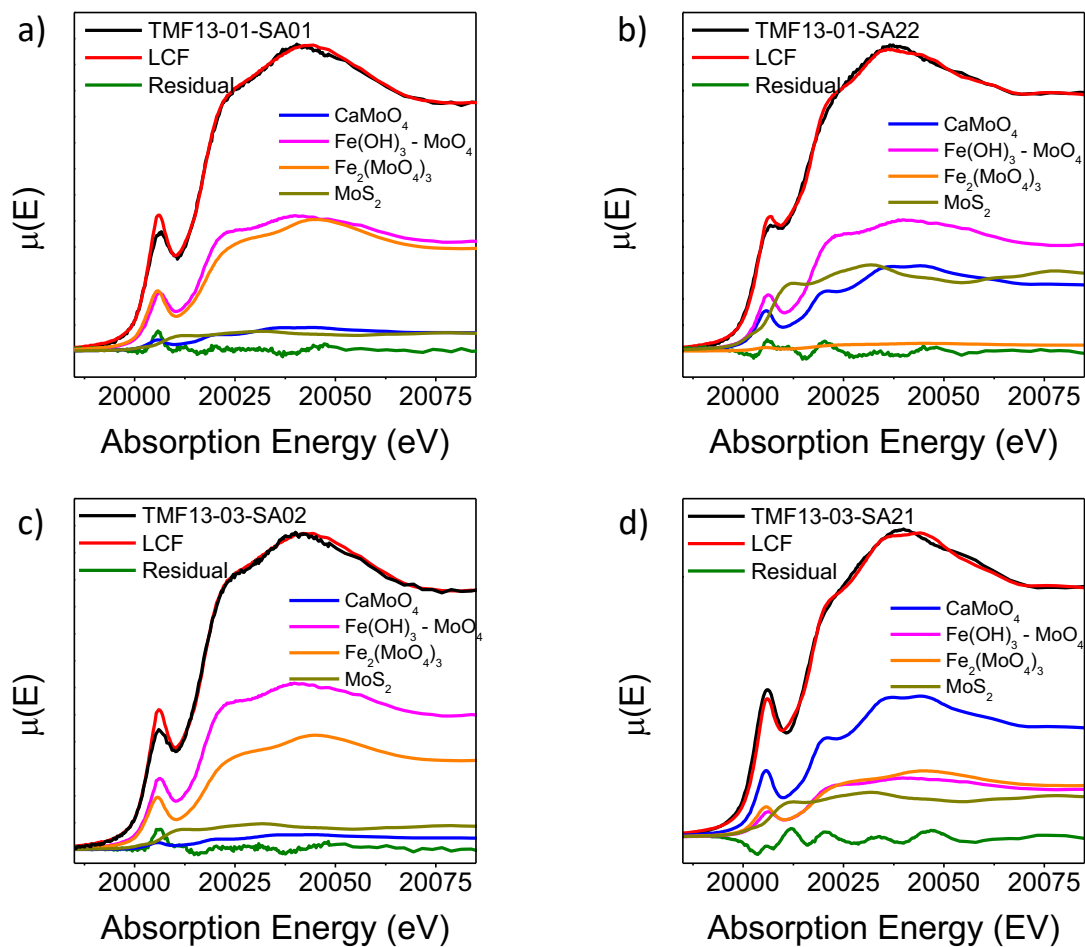


Figure 4

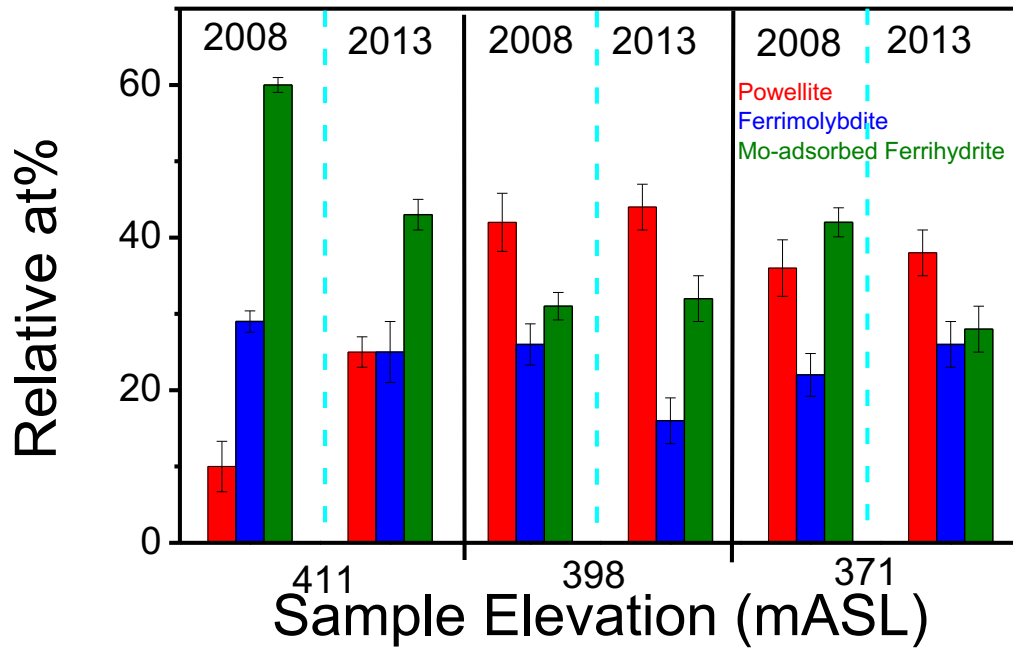


Figure 5

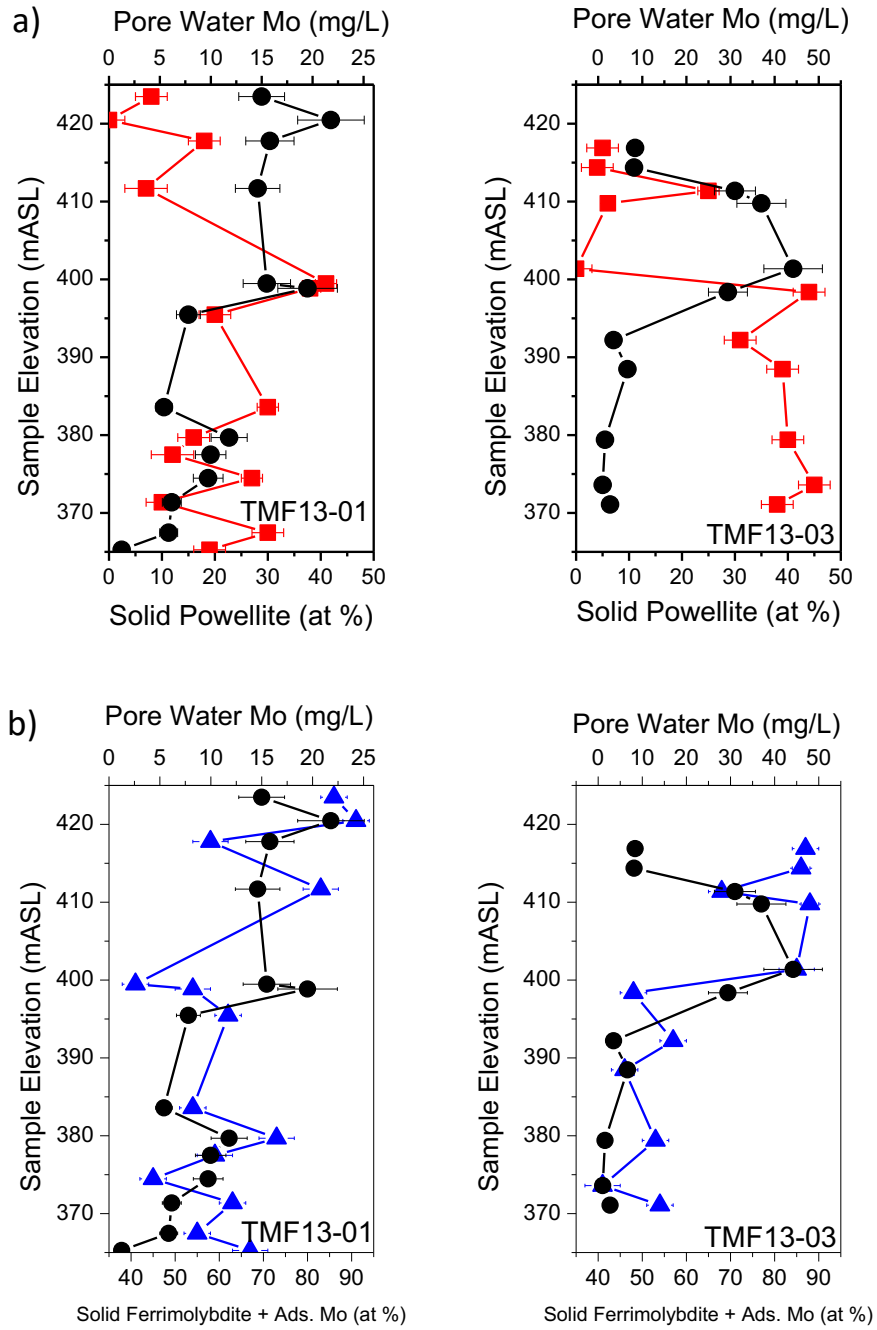
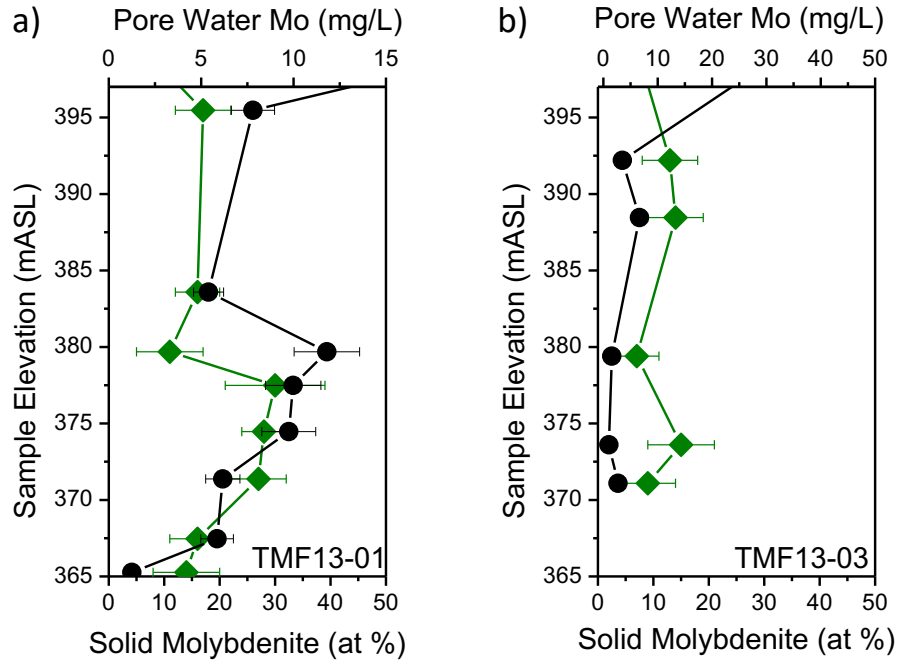


Figure 6



TOC Graphic

