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Hydrogeochemical impact of coarse-grained post-glacial acid sulfate soil materials

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ABSTRACT

Acid sulfate (a.s.) soils have long been under investigation in Finland due to their negative impact on the environment. Earlier studies have mostly focused on fine-grained (< 63 μm) a.s. soil materials, but acidification caused by coarse-grained (≥ 63 μm) post-glacial a.s. soil materials has recently gotten more attention. Using a "let the soil speak for itself" incubation approach, we investigated six soil profiles consisting of mostly coarse-grained potential a.s. soil materials in a study area in western Finland. Although the sulfur concentrations and acidities in the reduced sulfidic coarse-grained parent materials were significantly lower (10–100 times) compared to fine-grained a.s. soil materials, the pH-values were similar and well below 4.0 for most samples after a 16-week (incubation) oxidation period. The coarse-grained materials also oxidized rapidly and displayed a fast drop in pH during the incubation. This was most likely due to a poor buffering capacity caused by the low specific surface and a quartz-feldspathic mineralogy, which is likely to cause a rapid leaching of acidity. No actual a.s. soil materials (pH < 4.0) were observed in the sampled soil profiles but are likely to occur within the study area; since all, besides one, of the sampled soil profiles contained potential a.s. soil materials. Acidity and metal problems were common in a nearby groundwater area utilized for drinking water, where Al, As, Cr, Co, Fe, Mn and Ni concentrations were elevated at least 10 times over background median values. In addition, oxidation of coarse-grained a.s. soil materials appear to have caused the pH to decrease as low as 3.4 in several sand pit lakes, formed by sand mining, where median levels of SO_4, Al, Mn, Ni, Se and Zn were elevated > 10 times over background concentrations. We suggest that there is a strong link between the oxidation of coarse-grained post-glacial a.s. soil materials and a high acidity and elevated metal concentrations in groundwater and sand pit lakes.

1. Introduction

Acid sulfate (a.s.) soils are considered "the nastiest soils in the world" (Dent and Pons, 1995). Formation of actual a.s. soils occurs when sediments rich in sulfide minerals, such as pyrite and various metastable iron-sulfides (such as mackinawite and greigite), come in contact with oxygen, which causes an oxidation of the sulfides. The oxidation process produces sulfuric acid, which in turn lowers the pH (< 4.0) and causes severe metal leakage by dissolving phyllosilicates, other sulfides and several oxides (Åström, 1998; Åström and Björklund, 1995). The proposed definition of potential a.s. soil materials by Sullivan et al. (2010) suggest that soil materials containing sulfidic sulfur ($S_{sulfidic}$) ≥ 100 mg/kg and that cause severe acidification (pH < 4 during incubation) should be termed hypersulfidic, whereas sulfidic ($S_{sulfidic}$ ≥ 100 mg/kg) materials which do not produce an incubation pH < 4 are termed hyposulfidic. If subjected to oxidation, hypersulfidic materials will form actual a.s. soils with sulfuric (pH < 4) soil horizons and result in environmental harm. Undisturbed hypersulfidic soil materials are therefore potential a.s. soils and should be managed appropriately or left untouched.

The coastal areas in Finland are heavily impacted by a.s. soil drainage and it is estimated that one third of the coastal waters (marine and inland) are negatively influenced by a.s. soils (cf. Roos and Åström, 2005). The total extent of actual and potential a.s. soils in Finland is in the order of 2600 km^2 or more (Beucher et al., 2015). Because of the environmental hazards posed by a.s. soils in Finland, a national mapping program started in 2009 to investigate actual and potential a.s. soils. During the mapping, the main attention was initially on fine-grained actual a.s. soils while coarse-grained soil materials were considered non-hazardous even though acidifying effects of such soils have been documented, e.g. in Australia (Dear et al., 2014). Moreover, as the

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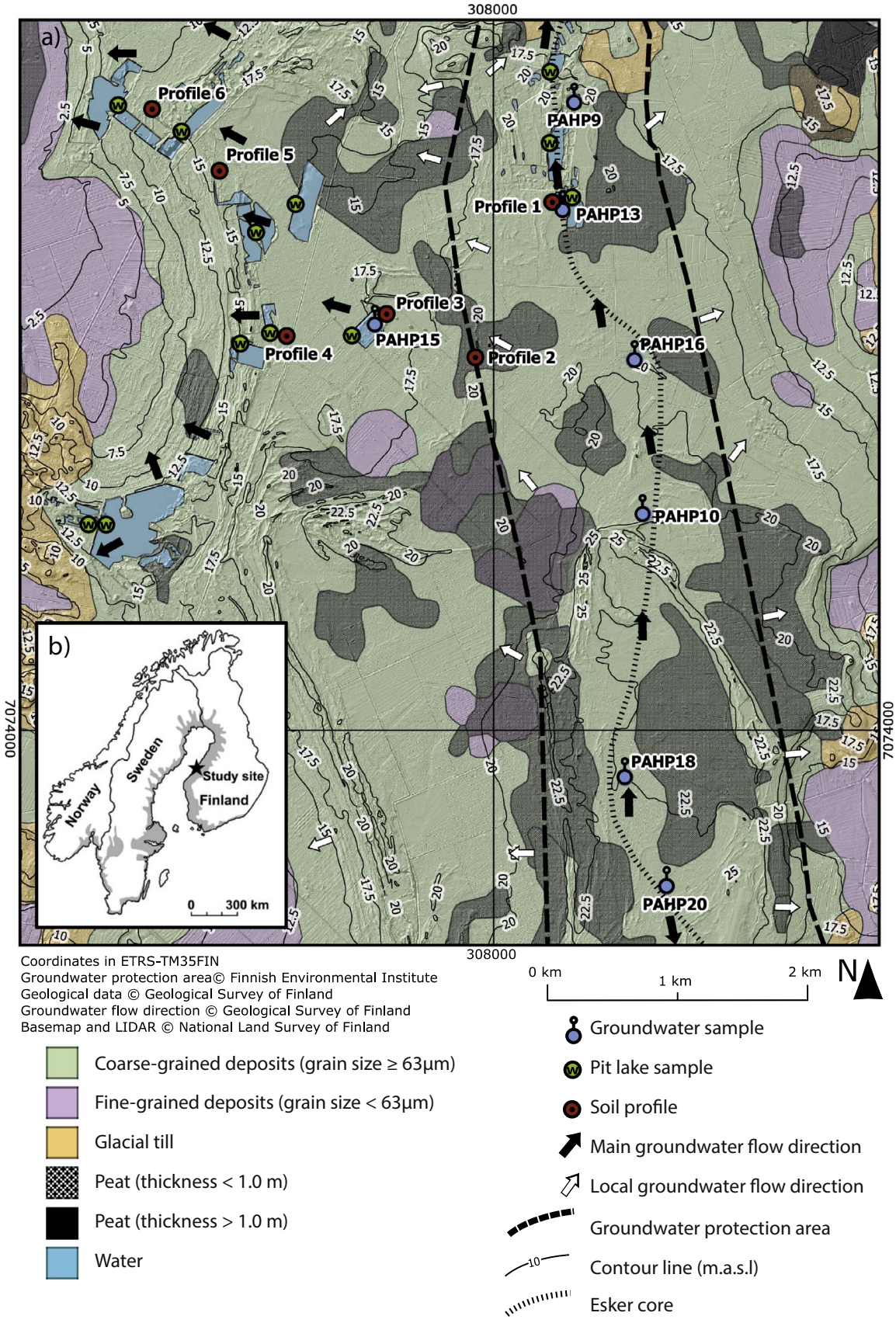

Fig. 1. a) Map of superficial deposits (to a depth of 1.0 m) in the study area with the sampling points for 6 soil profiles, 12 sand pit lake samples and 6 groundwater samples marked. b) Location of the study site with the former Littorina sea extent shaded.