The linkage between the microbial diversity and mineral weathering in soil

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Introduction

Soil microorganisms play an important role in mineral weathering and biogeochemical cycling of iron. In soil, microorganisms can synthesize siderophores with high affinities for metals as a strategy to promote the mineral dissolution and obtain the element nutrition. The present study aims to 1) study the microbial diversity and siderophore composition in a podzol soil profile, 2) and investigate the distribution of the siderophore producing microorganisms in the soil and their ability of hydroxamate siderophore production

Sampling site

Soils were sampled in September 2011 from central Sweden in the vicinity of the village Bispgården (63 07′N, 16 70′E). The site is located on a slope (angle 2) at an altitude of 258 m above sea level and is forested with 80-yr-old Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*). The soil is a typical haplic podzol.

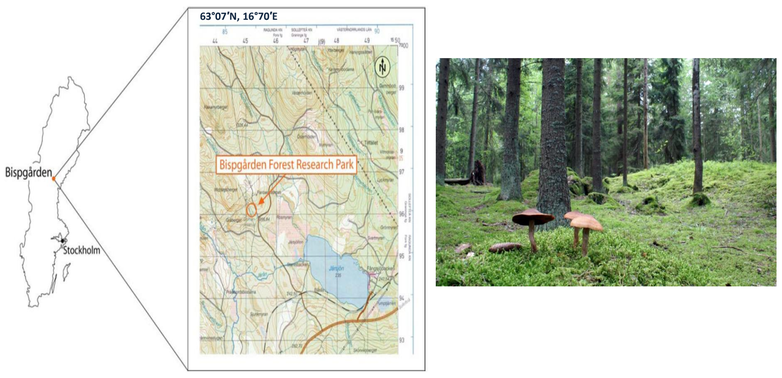

Fig 1. Sampling area

Soil samples were collected from O- (organic), E- (eluvial), B- (upper illuvial), and C- (parent material) horizons of the podzol profile.

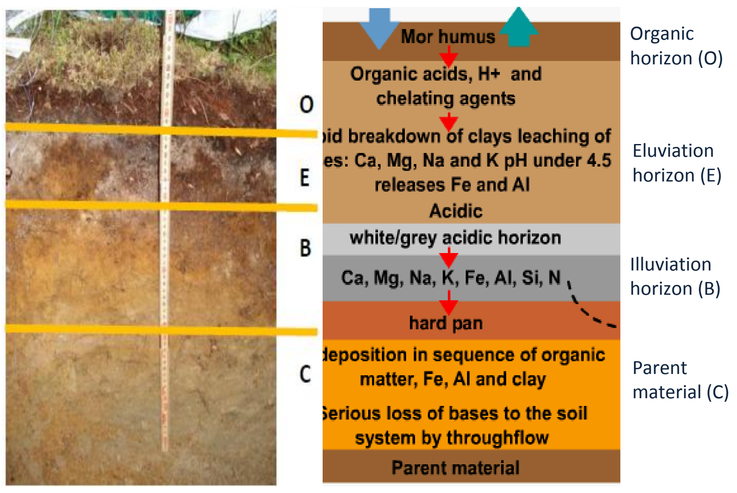

Fig 2. Podzol soil profile

Methods

Microbial diversity	Total DNA was extracted, and 16S and 18S genes were sequenced by MiSeq, Illumina.
Siderophore producing microorganisms	Siderophore producing bacteria and fungi were isolated from the whole profile and were genetically identified.
Siderophore quantification	Siderophores were extracted from both the soil samples and microbial cultures. Hydroxamate siderophores i.e. ferrioxamines, ferrichromes, fusigen and coprogens were detected and quantitated by HPLC-ESI-MS.

Microbial diversity in soil profile

Our findings indicated that there was a high diversity of different bacterial and fungal classes within the soil profile.

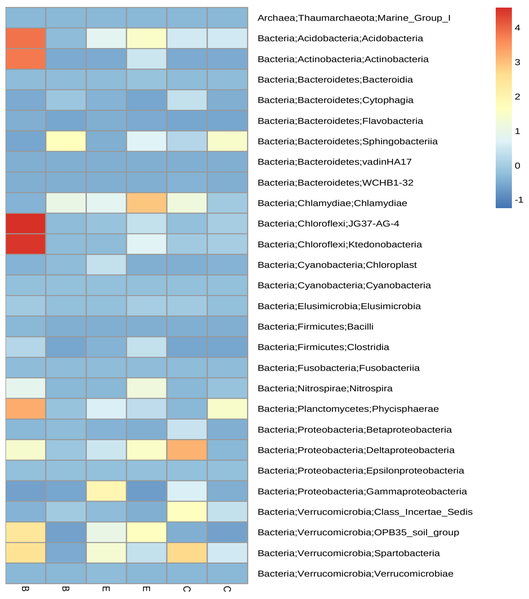

Fig 3. Bacterial diversity in the soil profile

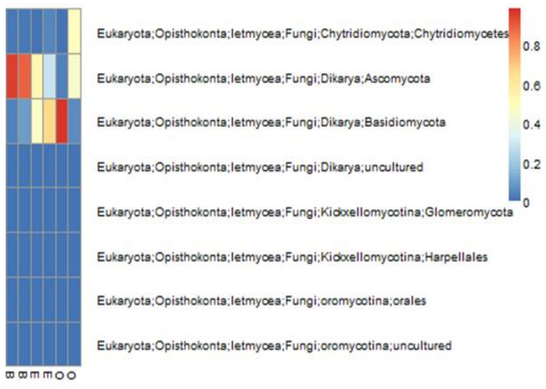

Fig 4. Fungal diversity in the soil profile

*Ahmed, E., et al., In preparation.

Siderophore producing microorganisms

The siderophore producing bacteria and fungi were highly distributed throughout the soil profile. The maximum taxa were present in E-horizon, whereas the minimum taxa were found in C-horizon.

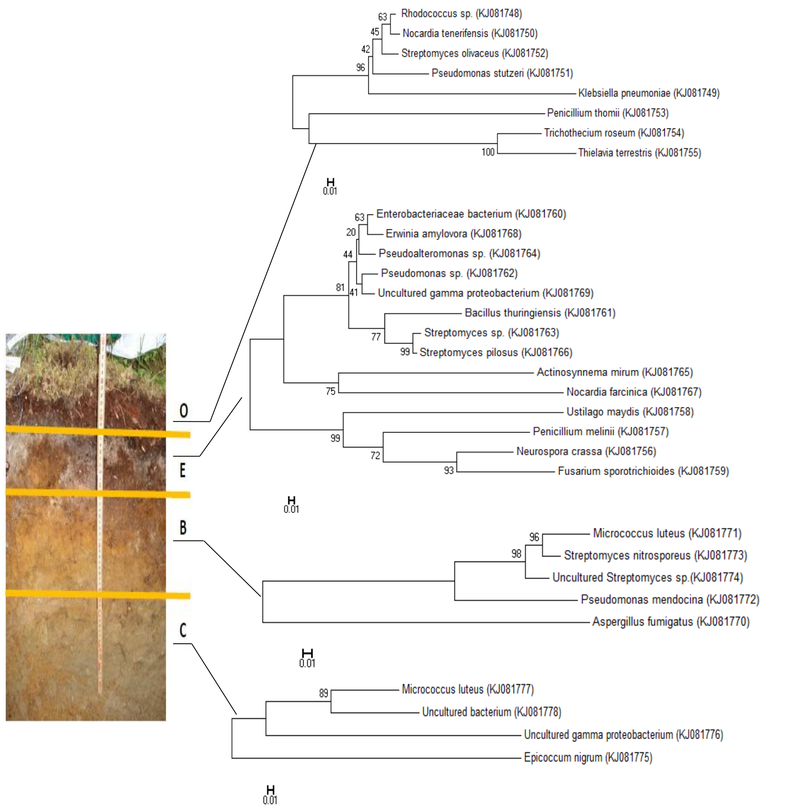

Fig 5. Distribution of siderophore producing microorganisms throughout the soil profile

*Ahmed, E., and Holmström, S.J.M., 2014. Siderophore production by microorganisms isolated from a podzol soil profile. Geomicrobiology J. In press.

Siderophore composition in soil profile

A wide range of fungal hydroxamates (ferrichromes, coprogens and fusigen) and bacterial hydroxamates (ferrioxamines) were detected in the soil solution extracts. That was the first time where coprogens and fusigen siderophores have been detected in soil, and they were found to be the predominant types throughout the soil profile.

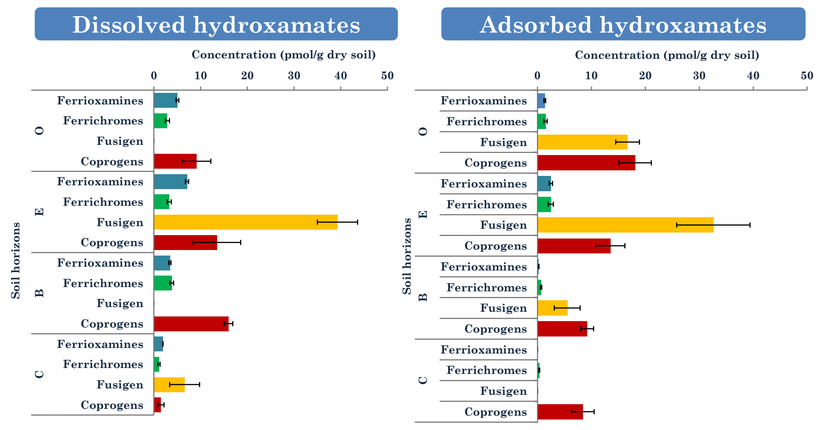

Fig 6. Dissolved and adsorbed hydroxamates the soil profile

*Ahmed, E., and Holmström, S.J.M., 2014. The effect of soil horizon and mineral type on the distribution of siderophores in soil. Geochim. Cosmochim. Acta 131, 184-195.

Siderophore production by microorganisms

The siderophore producing bacteria showed different abilities in the production of ferrioxamines (E, B, G and D).

Table 1. Hydroxamate production by bacterial species

	Ferrioxamines (nM)			
Horizon/Microorganisms	**FOX B**	**FOX G**	**FOX D**	**FOX E**
HORIZON ^O^				
Streptomyces olivaceus	14.1	21.7	18.6	-
Pseudomonas stutzeri	9.4	1.6	1.3	1.2
Nocardia tenerifensis	8.1	14.1	16.6	-
Klebsiella pneumoniae	14.7	18.2	8.4	-
Rhodococcus sp.	-	17.5	16.0	3.7
HORIZON ^E^				
Enterobacteriaceae bacterium	11.8	21.3	0.8	0.7
Bacillus thuringiensis	13.7	14.4	9.6	1.1
Pseudomonas sp	6.7	12.7	13.5	3.9
Streptomyces sp.	19.3	15.5	11.1	-
Pseudoalteromonas sp.	7.9	13.2	13.8	4.3
Actinosynnema mirum	8.9	-	8.1	-
Streptomyces pilosus	15.3	19.7	10.8	-
Nocardia farcinica	9.6	6.7	14.5	-
Erwinia amylovora	7.7	11.7	7.3	1.6
Gamma proteobacterium	-	16.2	16.3	4.1
HORIZON ^B^				
Micrococcus luteus	5.0	2.8	7.2	1.5
Pseudomonas mendocina	-	2.8	14.6	11.4
Streptomyces nitrosporeus	17.5	24.3	10.8	-
Uncultured Streptomyces sp.	11.4	13.2	16.3	-
HORIZON ^C^				
Uncultured gamma proteobacterium	-	-	0.9	2.9
Micrococcus luteus	-	-	-	5.0
Uncultured bacterium	-	18.4	6.9	-

The siderophore producing fungi showed a high variety in the production of ferrichromes, coprogens and fusarinines.

Table 2. Hydroxamate production by fungal species

	Ferrichromes (nM)						Coprogens (nM)				Fusarinines (nM)
Horizon/Microorganisms	**FCH**	**FC**	**Tetra-FCH**	**FCHR**	**FRU**	**FCH A**	**Fe-DA**	**Neo-COP II**	**Neo-COP I**	**COP**	**FUS (lin.)**
HORIZON ^O^											
Penicillium glabrum	-	-	1.8	0.01	-	-	0.9	-	-	304.7	-
Thielavia terrestris	-	0.2	4.4	0.05	0.7	-	-	-	-	-	-
Trichothecium roseum	0.1	-	-	-	0.3	-	-	4.8	-	101.3	-
HORIZON ^E^											
Penicillium melinii	0.6	-	-	-	-	-	-	-	-	539.7	-
Ustilago maydis	-	-	-	-	-	-	-	6.0	-	1649.3	-
Neurospora crassa	-	-	-	-	-	-	0.81	5.9	-	892.7	-
Fusarium sporotrichioides	-	-	1.0	-	-	-	-	3.1	81.1	462.4	14.9
HORIZON ^B^											
Aspergillus fumigatus	-	-	19.3	0.04	4.1	-	8.9	-	-	-	-
HORIZON ^C^											
Epicoccum nigrum	-	-	-	-	-	10.7	-	4.5	-	514.4	-

*Ahmed, E., and Holmström, S.J.M., 2014. Siderophore production by microorganisms isolated from a podzol soil profile. Geomicrobiology J. In press.

Conclusion

Our findings reflected that the habitat of each soil horizon in the podzol profile could not only affect the diversity of the soil microbial communities, but also enhance the siderophore biosynthesis by inhabiting microorganisms, therefore may enhance the microbial ability in soil mineral weathering.

Acknowledgments

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