Spatial and Process-based Modeling of Inorganic Carbon Storage in the Mojave Desert

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Introduction

Many important pedogenic processes in arid environments are strongly liked to geomorphology. The overall goal of this project is to couple geomorphology with a process-based model in order to predict the spatial distribution of calcium carbonate across a Mojave landscape.

Objectives

1. Evaluate the assumptions of existing models relevant to calcite precipitation
2. Characterize the effect geomorphology has over model parameters and spatial distribution of pedogenic carbonates across a landscape
3. Validate the model and spatial predictions in the field
4. Interpret model-geomorphic interactions as a means of soil inorganic carbon (SIC) inventory in the Mojave Desert

Study site

This study will be conducted on an alluvial fan complex of the Soda Mountains, to the west of Silver Lake playa, eastern Mojave Desert, CA (Fig. 1)

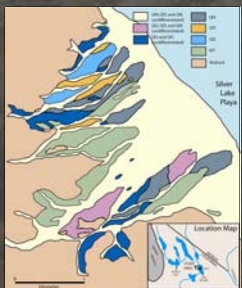

Figure 1. Map of the study area, showing Quaternary fan deposits Qf1 to Qf6 (modified from Reheis et al., 1989)

Hypotheses

1. Saturated water flow and thermodynamic expressions for calcite chemistry can reasonably be assumed over the time periods simulated.
2. Solid-phase precipitation significantly affects hydraulic conductivity and thus the distribution of carbonates in a profile.
3. Calcium/carbonate bearing mineral and silicate weathering chemistry is important to the accumulation and distribution of carbonates.
4. Soil-geomorphic information coupled with process-based modeling can accurately simulate carbonate accumulation across a landscape.

Research plan

Testing model assumptions:

1. Hypotheses 1-3 will be tested using HYDRUS-1D coupled with UNSATCHEM
2. HYDRUS code will be modified to account for pore-size distribution changes caused by mineral precipitation using a film depositional model proposed by Freedman et al. (2004)
3. Assumptions will be tested by comparing the model results from the 16 combinations presented in Table 1

Table 1. Combinations of model assumptions

Model Simulation	Assumptions: Chemistry[1]	Water flow[2]	Source of calcium[3]	Hydraulic conductivity change[4]
1	T	U	D	Y
2	T	U	D	N
3	T	U	DS	Y
4	T	U	DS	N
5	T	S	D	Y
6	T	S	D	N
7	T	S	DS	Y
8	T	S	DS	N
9	K	U	D	Y
10	K	U	D	N
11	K	U	DS	Y
12	K	U	DS	N
13	K	S	D	Y
14	K	S	D	N
15	K	S	DS	Y
16	K	S	DS	N

[1]T=thermodynamic equilibrium, K=chemical kinetics; [2]S=saturated flow, U=unsaturated flow; [3]D=dust, DS=dust and silicate weathering; [4]Y=yes, N=no

Simulating the spatial distribution of carbonates:

1. Create a digital elevation model (DEM) of the alluvial fan complex
2. Measure surface/soil characteristics including vegetation type and density, surface clast cover, soil texture, bulk density, and carbonate accumulation
3. Delineate map units based on estimated amount of water infiltrating into the soil
4. Model carbonate accumulation and distribution using appropriate model assumptions
5. Compare model results with measured data

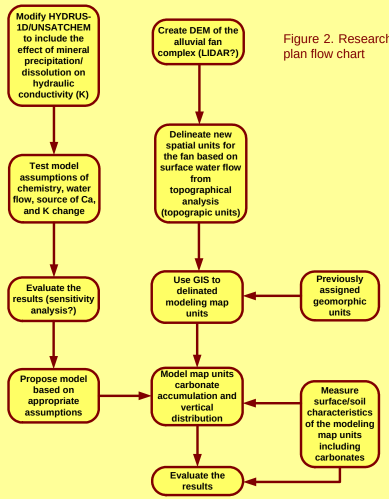

Figure 2. Research plan flow chart

Results of previous studies

Previous work has yielded information about the surface ages (Table 2) and profile descriptions of these deposits (Table 3)

Table 2. Surface ages of deposits listed in Fig. 1

Fan deposit	Surface age (ka)
Qf6	<0.05
Qf5	0.2
Qf4	2
Qf3	6
Qf2	11
Qf1	35

Table 3. Soil profiles of deposits listed in Fig. 1

Fan deposit	Taxonomy	Horizon	Depths (cm)	Texture	$CaCO_3$ Stage
Qf1	Typic Haplargid	A	0-0.1	SL	0
		Av	0.1-5	L	0
		Btk1	5-15	SL	I
		Btk2	15-27	LS	I
		2Bkyz	27-40	S	II-
		3Bk	40-68	S	II+
		3Bkq1	68-105	S	II
		4Bkq2	105-175	S	I+
		4Bkq3	175-210	S	I
		4BCq	210-250	S	I
Qf2	Typic Haplargid	A	0-1	S	0
		Av	1-7	SCL	0
		Btk	7-23	SL	I-
		Bwky	23-36	LS	I
		Bkyq1	36-80	LS	II-
		2Bkyq2	80-122	LS	II
		2Bkq	122-151	S	II
		3Btkb	151-200	LS	II-III
Qf3	Typic Torrifluvent	Av	0-5	L	0
		2Btj	5-12	S	I
		3Bky1	12-32	S	I
		4Bky2	32-48	S	I
		5Ck	48-60	S	I-
		6Bb	60-90	SL	0
Qf4	Typic Torrifluvent	A	0-0.2	fS	0
		Av	0.2-3	SL	0
		Bwk	3-10	S	I
		Bqj	10-48	S	I-
		2Bq1	48-68	S	I-
		2Bq2	68-117	S	I-
		3Bb	117-150		
Qf5	Typic Torrifluvent	Av	0-3	LS	0
		2C1	3-20	S	0
		3C2	20-35	S	0
		4C3	35-65	S	I-
		5Bb	65-70	SL	
Qf6		Channel alluvium		S	0

Summary

This project seeks to address a deficiency in knowledge of SIC storage. It proposes a methodology by which soil-geomorphic information is coupled with process-based modeling to predict SIC storage across a landscape. This research will test previous assumptions of carbonate precipitation and dissolution in arid soils.

References

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Freedman, V.L., D.H. Bacon, K.P. Saripalli, and P.D. Meyer. 2004. A film depositional model of permeability for mineral reactions in unsaturated media. Vadose Zone J. 3:1414-1424.

Acknowledgements

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