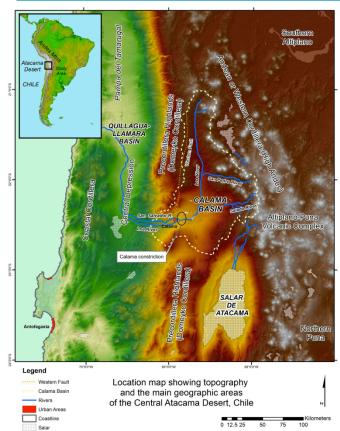
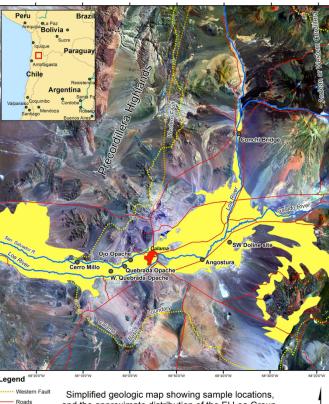


#### Overview

The Atacama Desert in Chile is currently the driest places on Earth, but only ~5 million years ago there was sufficient water to support a sizable freshwater limestone system--the Opache Formation. Located in the Calama Basin between the Andes and Pre-Cordillera, the Opache Formation represents deposition of lacustrine and palustrine origin. A previous pilot study reveals that limestone deposited east of the geographic restriction, "the Calama Constriction", formed in a lake system, while west of the gap, very shallow water, or palustrine, conditions predominated. This study focuses on the western Opache, where a 28.5 m thick stratigraphic section west of Calama was measured and sampled. Petrography and geochemical results show that oncolites, stromatolites, and gastropods, in a sandy micrite matrix, are relatively abundant. Concurrent with freshwater limestone deposition, the region was also influenced by volcanic ash falls, and episodic storm events that transported siliciclastic grains, revealing tectonic and climate interplay.

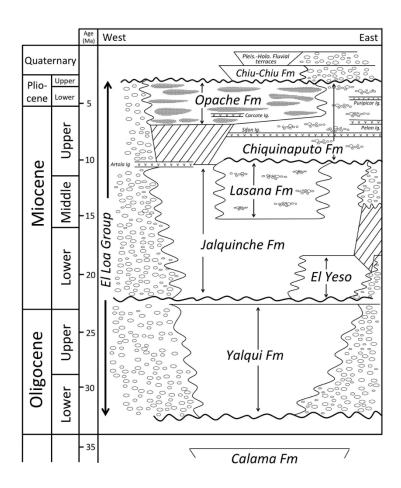




and the approximate distribution of the El Loa Group, Calama area, Chile 0 3 757 5 15 22 5 30

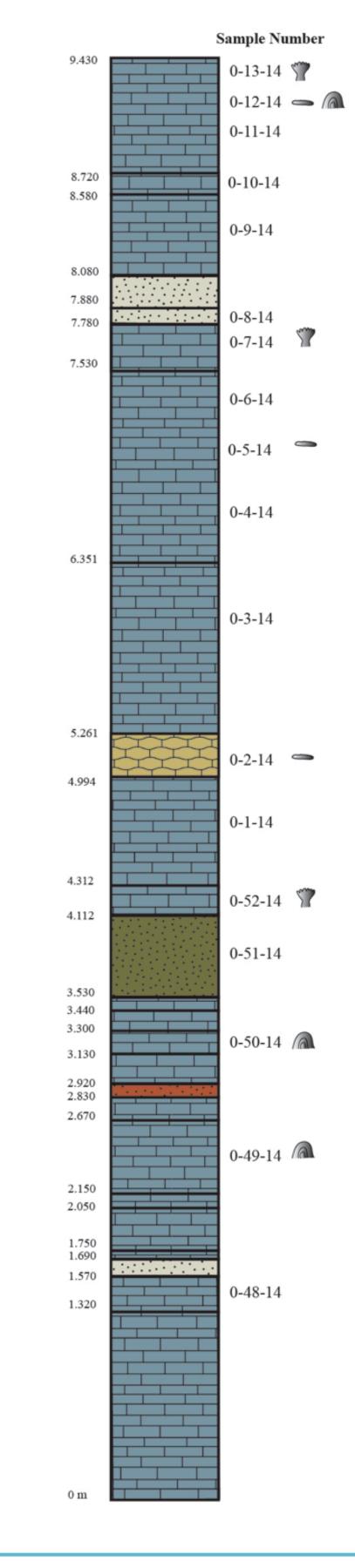
### Background

- Situated in the Atacama Desert, the Calama Basin is bound by the Andes to the east and the Pre-Cordillera highlands to the west.
- The Calama basin an ideal location to study climateresponsive carbonate depositional settings, because the hyperarid environment (rainfall <10mm/yr in the western part of the basin) preserves the excellent rock exposure incised by ancient El Loa River.
- The Opache Formation belongs to El Loa Group, where the majority of the formations are of siliciclastic origin, due to rapid tectonic uplift of the Cordillera.
- While Opache limestone was able to form during a window of tectonic quiescence, volcanic eruptions and flood events continued to bring in siliciclastic sediments.









Sample 0-25-14 comes from a pyroclastic ash bed, containing the minerals pyroxene, biotite, hornblende, and plagioclase. While the minerals in this sample are unaltered, volcanic glass shards are broken up. Samples up-section show well preserved "Y" shaped features, characteristic of vesicular volcanic glass. During a typical volcanic eruption these glass shards are reworked within the flow of the ash bed, losing their fragile shapes. After the flow event, the ash continues to fall, and glass shards are able to keep their pristine features. In our samples, we see both volcanic glass fragments, associated with igneous minerals, indicative of a pyroclastic flow, entering the palustrine setting, and unbroken glass shards, interpreted as ongoing ash fall deposits.

# Palustrine origin for western Opache Formation (Miocene-Pliocene), Calama Basin, Atacama Desert, Chile

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## **Stratigraphy of the Opache Formation** Legend Limestone 0-44-14 🛥 Mg-calcite/quartz/feldspar almandine/muscovite/feldspar Mg-calcite/calcium sulfate/quartz/KC -41-14 calcium sulfate/quartz calcite/calcium sulfate/quartz 0-43-14 0-40-14 ( calcite/calcium sulfate calcite/quartz/calcium sulfate/albite -39-14 0-38-14 Mg-calcite/gypsum/quartz 60 0-37-14 calcite/gypsum/quartz z/KCl 22.06 calcite/calcium sulfate/quartz 0-36-14 🔘 0-35-14 🐚 calcite/calcium sulfate 0-34-14 🐚 🛥 酇 calcite/quartz/feldspar/gypsum 0-33-14 🔘 calcite/calcium sulfate 0-32-14 calcite/gypsum 0-31-14 calcite/quartz/anorthite/gypsum

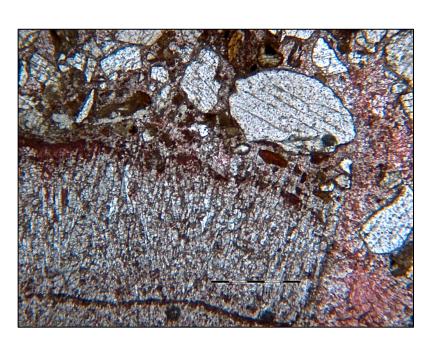
calcium sulfate/quartz/			
nalite/anorthite/gypsum			
calcite/quartz/cristobalite/felds	spar		
calcite/quartz/cristobalite/anor	thite		
ealcite/quartz/feldspar/KCl			
ealcite/quartz/calcium sulfate/ eldspar			
Mg-calcite/calcium sulfate			
ealcite/quartz/calcium sulfate			
ealcite/quartz			
ealcite/quartz			
calcite/gypsum			
calcite/quartz/feldspar/gypsum/clay mineral illite/glauconite, or muscovite)			
calcite			

uartz/calcium sulfat

calcium sulfate/feldspar

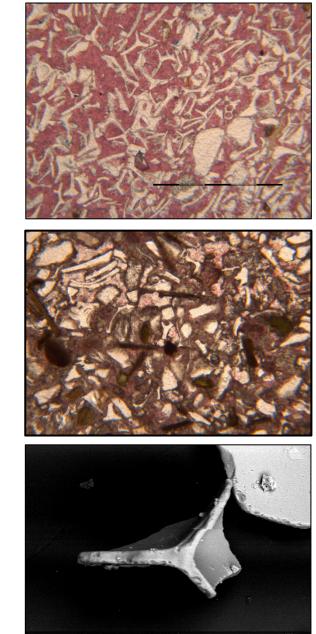
calcite/calcium sulfate/trace of aragonite

calcite/quartz



18.94		0-30-14		calcite/quartz
18.83				1
18.64		0-29-14		calcita/avnsum
18.47 18.38		0-29-14		calcite/gypsum
18.15		0-28-14		calcite/KCl
17.97		0-27-14		calcite
17.85		0-26-14		calcite/quartz/calcium sulfate/
				feldspar
17.38 17.24		0-25-14		Mg-calcite/quartz/
				cristobalite/anorthite
15.99				
15.81				
		0-24-14		Mg-calcite/quartz/calcium sul
				5
15.16		0.22.14		calcite/quartz/KCl/feldspar
15.02		0-23-14		eulene/quiliz/res/teluspui
14.28	$\begin{array}{c} \downarrow  \downarrow  \downarrow  \downarrow  \downarrow  \downarrow  \downarrow  \downarrow  \downarrow  \downarrow $			
				1
		0-19-14		calcite/quartz
12.79				
		0-18-14		calcite/calcium sulfate/quartz/
11.90		0-17-14		calcium sulfate/calcite/quartz
11.65		0-17-14		calefulli sufface/calefic/quartz
		0-16-14		Mg-calcite/quartz
11.13				
		0-15-14	0	calcite/quartz
10.67				
		0-14-14		calcite/calcium sulfate/quartz
	THE			

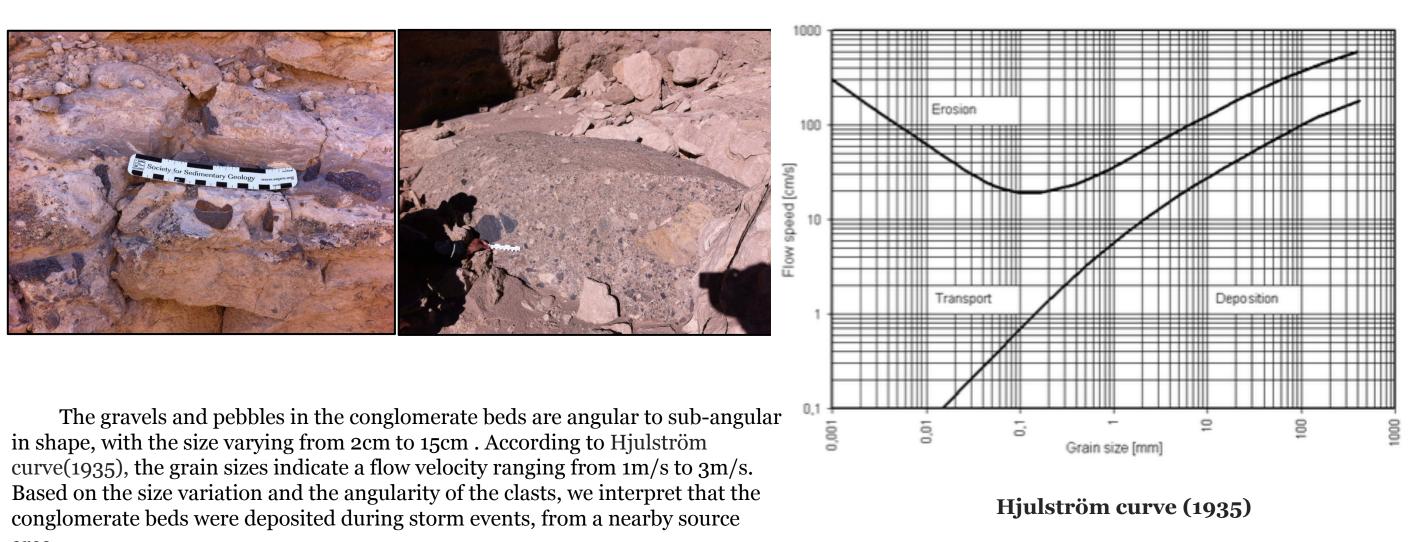
### Volcanic Ash



Sample 0-25-12 in thin section

ample 0-25-14 in hin section

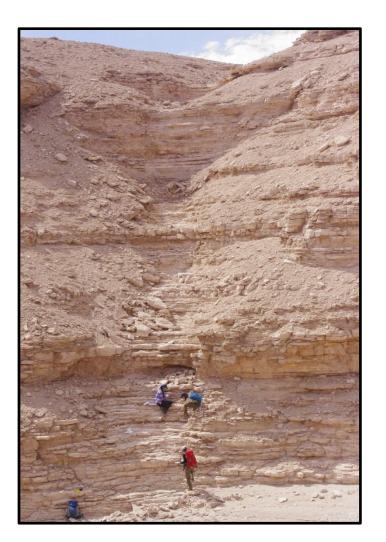
SEM photo of sample 0-25-12.



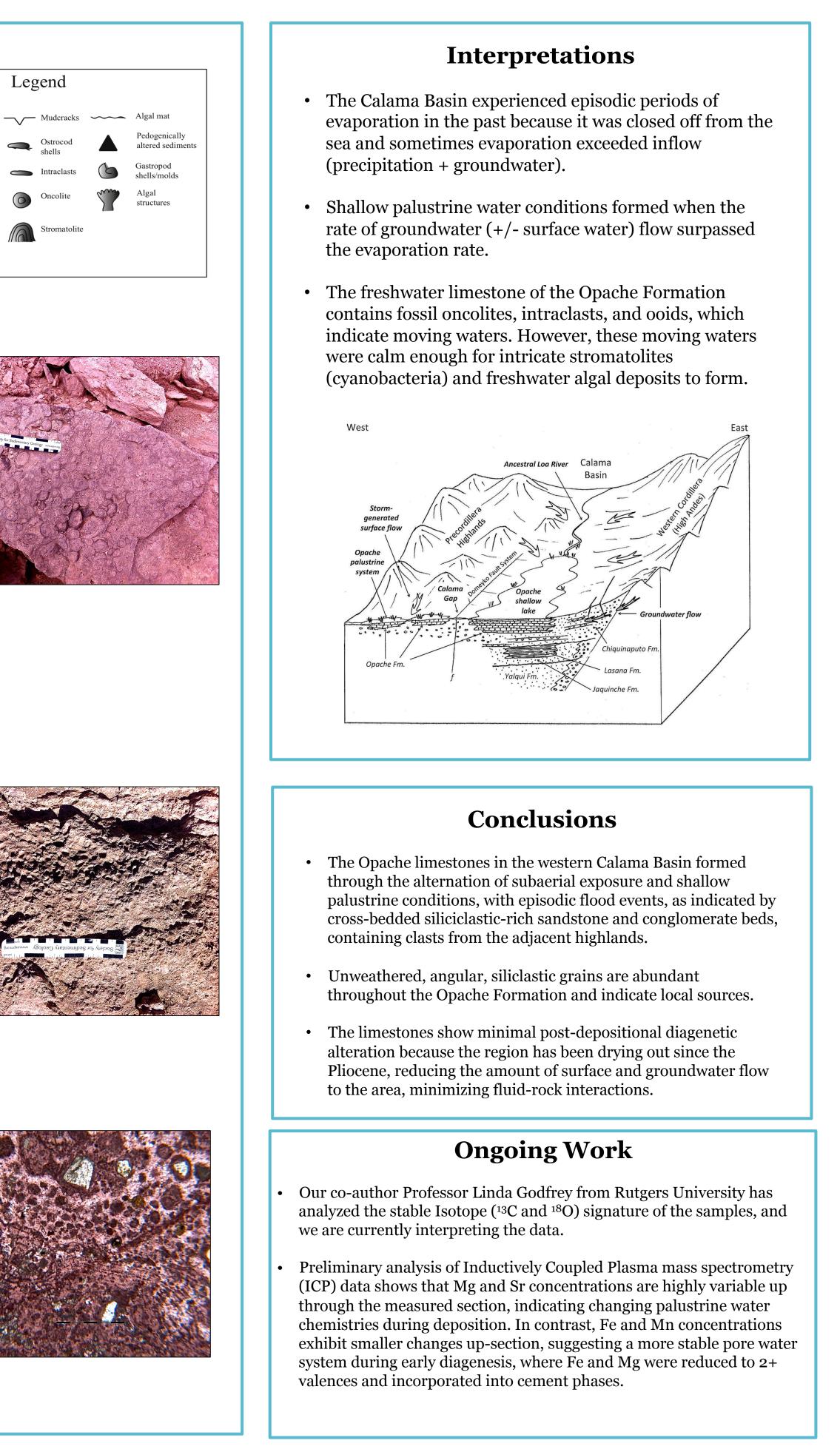
area.



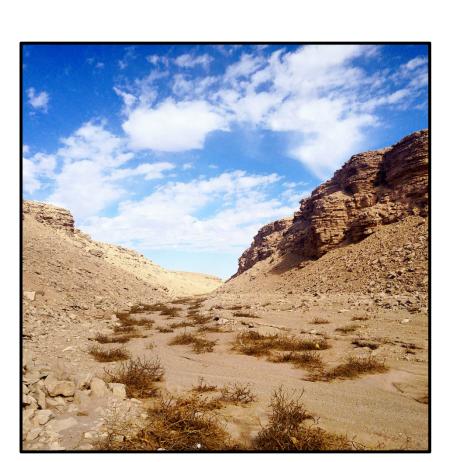
### Grain size and flow velocity



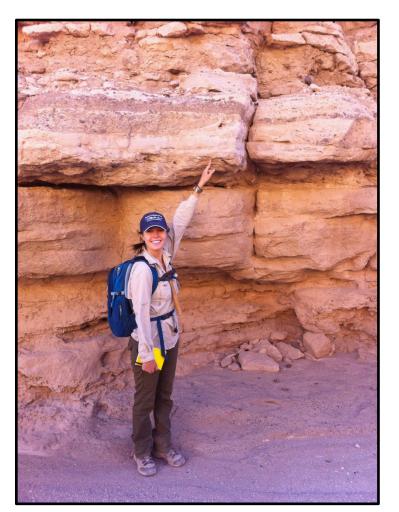
Site west of Calama, exposed measured section, ~24 m.







Looking down section in the Calama Basin



Pointing to basal flood deposit scour.