SUPPLEMENTARY INFORMATION

Early Holocene major climate shift along the semi-arid coast of western South America

Dune systems evolution at Los Vilos area

Five dune systems (D1, D2, D3, D4 and D5) were defined based on the orientation of their crests, the vegetation and the available numerical ages. The oldest system (D5 in Fig. 2) is a polygenetic paleodune constituted by a large deposit of consolidated to semi-consolidated sand covering a wide area, giving the landscape a smooth relief with deep gullies. The thickest sand accumulation is at least 30 m thick at Agua Amarilla, situated within a depression in front of the Conchalí Bay which is limited to the north by a marine terrace and to the east by the Coastal Range. The stratification shows a preferential southwest wind direction and two extensive cemented sand layers ~15 cm thick within the paleodune, which suggests two stages of weathering and formation of soil, and therefore, at least three different stages of dune deposition. Furthermore, considering the large amount of sand needed to form this deposit, at least the last phase should have occurred during the Last Glacial Maximum, when the marine platform was partially exposed (Fig. 2). The D1, D2, D3 and D4 dune systems are unconsolidated, younger, and smaller than D5, as they were successively deposited over the paleodune. An age obtained from a *Mylodon* sp. vertebrae covered by D4 at the El Membrillo archaeological site (Jackson, 2003) (see Fig. 2 and LV.105 in Table 1), indicates that D4 was deposited after 16,000 cal yr BP. According to ages of marine shells and on rocks exposed to fire from three archaeological levels at the Ñagué site (Jackson 1993; Roman y Jackson 1998; Jackson and Méndez, 2005) (LV.98A in Table 1), D3 and D2 would have been deposited during the period *ca.* 13,000–9550 cal yr BP.

Finally, dating marine shells and rocks exposed to fire from an archaeological site at Agua Amarilla (LV.166 in Table 1) indicates that D1 would have been generated close to 7800 cal yr BP (Jackson, 2002), when the sea was reaching its current level according to global reconstructions (Lambeck, 2002). Altogether, they constitute a complex system formed by transverse dunes, and the disposition of the dune crests evidenced predominant southwesterly winds. Furthermore, the decreasing volume that younger dunes exhibit with respect to the older dunes would have been associated to the rise of the sea level which reduced the exposed shelf since the Last Glacial Maximum.

References

Jackson, D., 1993. Datación radiocarbónica para una adaptación costera del Arcaico Temprano en el Norte Chico, Comuna de los Vilos. Boletín de la Sociedad Chilena de Arqueología 16, 28–31.

Jackson, D., 2003. Evaluating evidence of cultural associations of Mylodon in the semi-arid region of Chile. In: Miotti, L., Salemme, M., Flegenheirmer, N. (Eds.), Where the South Winds Blow, Ancient evidence of Paleo South Americans. Center for the Study of the First Americans, College Station, pp. 77–81.

Jackson, D., Méndez, C., 2005. Primeras ocupaciones humanas en la costa del semiárido de Chile: patrón de asentamientos y subsistencia. Actas del XVI Congreso Nacional de Arqueología Chilena, pp. 493–502.

Lambeck, K., Esat, T., Potter, E., 2002. Links between climate and sea levels for the past three million years. Nature 419, 199–206

Roman, A., Jackson, D., 1998. Dataciones por termoluminicencia de rocas de fogones de asentamientos arcaicos, Provincia del Choapa. Chungará 30, 41–48.

N°	Rainy event date	Rainfall	Duration***	Meteorological Mechanism	Oceanic Niño Index	Effects at La Serena surroundings (Coquimbo Region)	Effects at Chile scale	References
1	1950, May 13 and 19	25.6 mm (May 13) and 9.4 mm (May 18), 21.4 mm (May 19) at La Serena *	> 5 hrs (May 13)	Blocking	-1.3 (La Niña)	(May 13) Partial damage of corn crops and fruits	No report of damages	El Día**: 1950 (May 13-14,17,19-21)
		Only monthly information available: 107.9 mm (May) at Puerto Oscuro *	> 16 hrs (May 19)			(May 19) Highway interrupted between Illapel and Ovalle	(May 13) Rain fell from Magallanes (52°S) to Talca (35°S)	
							There were droughts 6 years prior to 1950	
2	1952, June 23	8.2 mm (June 22) and 45 mm (June 23) at La Serena*	> 18.5 hrs	Blocking	-0.3 (Neutral)	Flooding in some villages	-	El Día**: 1952 (June 25)
		Only monthly information available: 104.9 mm (June) at Puerto Oscuro *				Elqui River with great flow and mud flow		
						Rainfall catalogued as beneficial to the area		
3	1957, May 20-25	10.2 mm (May 20) and 60.2 mm (May 21) at La Serena *	5 days	Deep Trough	0.7 (El Niño)	Great mud flow occurred on May 21 ranked one of the most catastrophic mud flows in history area. Cities full of mud and rocks. Elqui and Coquimbo rivers overflowed and devastated houses and everything in its path. La Serena and Coquimbo isolated. Small towns ravaged by rural ditches and streams. Wind and rain collapsed walls. Panamericana Highway cut into several large section. Hundreds of homeless.	The major storm affected central and northern Chile up to La Serena (30°S)	El Día**: 1974 (June 10), 1983 (June 11), 1991 (June 23)
		203.6 mm (average for Coquimbo region)**					20 dead and 4 thousand homeless	Urrutia and Lanza 1993: 279-280
		Only monthly information available: 180.3 mm (May) at Puerto Oscuro*						
4	1961, June 7-8	27 mm (June 7) and 7.5 mm (June 8) at La Serena*	30 hrs	Blocking	0.2 (Neutral)	Flooding in some villages. Collapse of walls. Roads cut off. Considerable damage in telephone service.	-	El Día**: 1961 (June 8)
		12.5 mm (June 6), 35.5 mm (June 7) and 6 mm (June 8) at Puerto Oscuro *				Post-drought rain. Without wind. Intensity of rainfall was unever across the region. Rain affected mainly the coastal area.		
5	1963, September 24	1 mm (September 22), 3 mm (September 23), 30.8 mm (September 24) and 1 mm (September 25) at La Serena*	> 5 hrs	Deep Trough	0.9 (El Niño)	Collapse of walls. Bad traffic conditions in transverse valleys. Collapse prevents the passage of trains. Intense rain falled up to Vallenar (28°S). One of the wettest years. Well distributed rains during the year, favorable for agriculture.	-	El Día**: 1963 (September 25-26)
		43.2 mm (September 25) at Puerto Oscuro *						
6	1965, July 12 and 17	0.3 mm (July 11), 42 mm (July 12) and 52.2 mm (July 17) at La Serena*	> 6 hrs (July 12)	Blocking	1.0 (El Niño)	(July 12) Flooding in some villages. Trees downed. Some landslides and rockfalls.	Storm in central zone	El Día**: 1965 (July 13 and 18)
		6 mm (July 12), 49 mm (July 13) and 1.8 mm (July 17), 38 mm (July 18) and 18 mm (July 19) at Puerto Oscuro *	~ 10 hrs (July 17)			(July 17) Telegraph interrupted. Houses flooded. Problems with tailings of Andacolllo. Traffic suspended to north and east of La Serena.		
7	1965, August 9-10	27.5 mm (August 9), 36.5 mm (August 10) and 1.5 mm (August 11) at La Serena *	> 17 hrs	Blocking	1.2 (El Niño)	Floods and landslides in whole province. Important roads and bridges cut by floods, e.g. Illapel-Los Vilos by Quebrada Canelillo and Illapel-Salamanca by Quebrada Lavaderos. Ports damaged by strong waves at Los Vilos and Pichidangui. Telegraph interrupted between La Serena and Santiago	48 hour storm from southern region to Antofagasta in the north.	El Día**: 1965 (August 10-12)
		50.6 mm (August 10) and 15.9 (August 11) at Puerto Oscuro *					90% of country suffered damage by the storm	
							Strong waves caused destruction in ports from Los Vilos (31°S) to Antofagasta (23°S)	
8	1966, June 13	23 mm (June 13) at La Serena*	Unknown	Blocking	0.2 (Neutral)	Rain fell throughout the province	Intense rainfall from Aysen (47°S) to Copiapó (27°S)	El Día**: 1966 (June 14-15)
		37.5 mm (June 14) at Puerto Oscuro*					Strong winds caused sandstorm that disrupted traffic between Calama (22°30'S) and San Pedro de Atacama (23°S)	
9	1972, June 13-14	37.2 mm (June 13) and 6.3 mm (June 14) at La Serena *	> 6 hrs	Blocking	0.8 (El Niño)	Part of the highway and roads cut by floods in ravines and landslide (with mud and rocks) from the hills. Houses flooded. Train traffic to the north and south of La Serena stopped .	The storm affected two thirds of the country	El Día**: 1972 (June 13-15)
		7.6 mm (June 13), 55 mm (June 14) and 1.2 mm (June 15) at Puerto Oscuro *						
10	1972, August 24	66.7 mm (August 24) and 2.6 mm (August 25) at La Serena*	> 12 hrs	Blocking	1.3 (El Niño)	Flooding and landslides. Trees falled. Power lines cut. Traffic interrupted. Streets of La Serena city seemed like rivers. Roads of whole province were affected by the storm, except Panamericana Highway and paved roads.	The most intense and persistent storm since the mud flow of 1957	El Día**: 1972 (August 25-26)
		35 mm (August 25) and 1 mm (August 26) at Puerto Oscuro*				Intense snowfall at Elqui Valley, more than 4 meters of snow at La Laguna dam.		
						At Los Vilos, fishing boat ran aground due to rough seas and intense wind		
11	1974, June 24-25	21.6 mm (June 24) and 0.7 mm (June 25) at La Serena*	> 10 hrs	Deep Trough	-0.8 (La Niña)	Some houses flooded	Rain fell from Concepción (37°S) to Vallenar (28°S)	El Día**: 1974 (June 25-26)
		32 mm (June 24) at Puerto Oscuro*					Low profile news	
12	1980, April 10-11	23.3 mm (April 10) and 2.1 mm (April 11) at La Serena *		Blocking	0.2 (Neutral)	Mud flow destroyed 30 meters of asphalt Panamericana Highway (Punitaqui community). Three points of the Panamericana Highway between La Serena and Santiago cut off. Strong discharge in the ravines of the region. Houses flooded. Closure of ports. Strong northwest wind at Los Vilos. Roofs blown off in Ovalle, Illapel and Los Vilos.	Strong storm (rain and wind) at Valparaíso (33°S)	El Día**: 1980 (April 9, 11-13)
		80 mm (April 9) and 64 mm (April 10) at Puerto Oscuro *					Homeless from Curicó (35°S) to La Serena (30°S)	
							April 6, unexpected and heavy rainfall cut off roads in Atacama Region (29 to 26°S)	
13	1981, May 12	3.9 mm (May 11) and 34.1 mm (May 12) at La Serena*	~ 16 hrs	Deep Trough	-0.3 (La Niña)	Falling rocks on Panamericana Highway	Wind storm and rainfall at Valparaíso (33°S)	El Día**: 1981 (May 12-13)
		2 mm (May 8), 1.9 mm (May 9), 2.3 (May 10) and 77 mm (May 11) at Puerto Oscuro*				Some flooding in streets of La Serena city. Some houses collapsed.		
						Record rainfall of Los Vilos, 110 mm in 12 hours		
						(May 11) Intense wind (60 km/hr) affected whole Coquimbo region from noon to evening. This caused rough seas (storm surge of 6 meters) at Coquimbo, without damage.		
14	1982, August 12-13	30 mm (August 12) and 6.5 mm (August 13) at La Serena*	~ 36 hrs	Cutoff low	1.0 (El Niño)	Collapse of a house. Some flooded houses. There were no major damages.	-	El Día**: 1982 (August 14)
		60 mm (August 12) and 4.6 mm (August 13) at Puerto Oscuro*				More benefits than damages for Coquimbo region.		

N°	Rainy event date	Rainfall	Duration***	Meteorological Mechanism	Oceanic Niño Index	Effects at La Serena surroundings (Coquimbo Region)	Effects at Chile scale	References
15	1983, July 6-8	6.9 mm (July 6), 69.5 mm (July 7) and 40.4 mm (July 8) at La Serena * 51.5 mm (July 6), 39 mm (July 7) and 18.5 mm (July 8) at Puerto Oscuro*	~ 40 hrs	Blocking	0.2 (Neutral)	Thousands of homeless. Mud flow at Peñuelas and flood at Fundición Coquimbo. Bridges with pillars undermined by the force of the flow (e.g. Estero La Herradura). Roads cut by strong currents in the ravines of the region. Ten towns isolated in Coquimbo region. Loss of crops.	-	El Día**: 1983 (July 8-12)
16	1984, July 1-5 and 8-10	62.8 mm (July 1), 17 mm (July 2), 0.3 mm (July 3), 43.5 mm (July 4), 3.2 mm (July 5), 24.7 mm (July 8), 4.2 mm (July 9) and 21 mm (July 10) at La Serena * 23.2 mm (July 1), 10 mm (July 2), 88 mm (July 4), 20.5 mm (July 5), 30.3 mm (July 8), 12 mm (July 9) and 73.5 mm (July 10) at Puerto Oscuro *	~ 4 days	Deep trough→Cutoff low	-0.3 (Neutral)	More than 35 thousand homeless in Coquimbo region. 9,639 homeless in La Serena. The flow of Quebrada Arrayán swept 100 meters of road and posts. Roads cut off and flooding in whole area. Mud and tailings flooded Andacollo. Craft stranded. Sheep hundreds drowned in Elqui River. Snow up to 180km east of the coast.	The storm affected a large part of Chile, from Punta Arenas (53°S) to Copiapó (27°S) Worst damage since 1957	El Día**: 1984 (July 2 - 17)
17	1987, July 11-16 and 24	5.8 mm (July 11), 26.9 mm (July 15) and 11.2 mm (July 16); 0.8 mm (July 23), 104.7 mm (July 24), 4.1 mm (July 25) at La Serena * 13.5 mm (July 10), 37.5 mm (July 11), 6 mm (July 12), 12 mm (July 13), 117 mm (July 14), 41 mm (July 15) and 6 mm (July 16); 17 mm (July 23), 59 mm (July 24) and 3.2 mm (July 25) at Puerto Oscuro *	3 days at La Serena (July 11-16) 7 days at Puerto Oscuro (July 10-16) ~ 12 hrs at La Serena (July 24) Unknown at Puerto Oscuro (July 24)	Deep trough→Cutoff low	1.4 (El Niño)	(July 11-16) Almost two thousand homeless in Coquimbo region. Traffic stopped north of Santiago. Elqui River caused the isolation of Altovalsol town. Roads cut and suspended by strong currents in the ravines of the region as e.g. at Conchalí bridge at Los Vilos. July (24) More than eight thousand homeless at Coquimbo region. Three people dead. Serious road damage, deep fissures in roads.	More than 100 thousand homeless in whole Chile Serious damages in south of Coquimbo region. Extensive damage in the province of Huasco, southern Atacama Region More than 100 thousand homeless in whole Chile	El Día**: 1987 (July 12 - 20; 25-30)
18	1991, June 16-19	9.6 mm (June 16), 42.9 mm (June 17), 4.5 mm (June 18) and 17.4 mm (June 19) at La Serena * 22.7 mm (June 16), 10 mm (June 18), 14 mm (June 19) and 25.7 mm (June 20) at Puerto Oscuro *	3 days	Blocking	0.8 (El Niño)	Rain and wind storm (30km/hr). Roads cut and bridges destroyed by strong currents in the ravines, transporting rocks and mud at Tongoy and Guanaqueros. 1,116 homeless in Coquimbo region. Elqui River level rose sharply. Huasco River flooded some sectors. Towns isolated. Snow up to 90 km east of the coast. Almost 100 cm of snowfall at La Laguna.	Mud flows at Antofagasta, northern Chile (23°S), caused 20 thousand homeless and 80 died. Strong winds up 100 km/hr at Tocopilla (22°S) Storm affected large part of Chile, from Rancagua (34°S) to Tocopilla (22°S) A cold front with post-front instability was reported by meteorologists on June 18	El Día**: 1991 (June 17-23)
19	1992, June 5-7	40.9 mm (June 5), 29.9 mm (June 6), 59.4 mm (June 7), 3mm (June 8) at La Serena * 62.5 mm (June 5), 24 mm (June 6) and 35 mm (June 7) at Puerto Oscuro *	2 days	Cutoff low	0.8 (El Niño)	Mud flow caused deep cracks (up to 2 meters) in streets because of flooding Jaramillo canal. Streets became rivers in Coquimbo. Strong winds destroyed roofs. Houses flooded. Power cut in Coquimbo. Strong winds at Los Vilos (up to 80 km/hr). 150 miners isolated at Los Pelambres and also 40 in Salamanca.	Roads cut between Antofagasta (23°S) and Tocopilla (22°S) 500 miners isolated in Atacama region Storm affected from Pto.Montt (42°S) to Arica (19°S) during last days of May until the early days of June More than 27 thousand homeless in whole Chile 738% superavit of rainfall.	El Día**: 1992 (June 6-10) Urrutia and Lanza 1993: 394
20	1997, June 11-12 and 18 and 21	1.7 mm (June 10)*, 26 mm (June 11)* and 32.2 mm (June 12) *; 11.6 mm (June 18) **and 17.5 mm (June 21)* at La Serena 8.1 mm (June 11), 32.2 mm (June 12) and 34.2 (June 13); 1.2 mm (June 18), 11.8 (June 19), 2.3 mm (June 20) and 2.8 mm (June 21) at Puerto Oscuro*	2 days (June 11-12) ~ 5 hrs (June 18) ~ 1 day (June 21)	Blocking	1.3 (El Niño)	(June 11-12) More than 4.500 homeless in Choapa province. Electric storm, heavy rainfall and hail at Coquimbo. Mud flow at Guanaqueros (June 13). Flooding Elqui River swept riverside vegetation away. Houses flooded. Roads cut by strong mud flows. Gabriela Mistral international route cut off. Isolated families. Bridges in Elqui town destroyed. Snow up to 180km east of the coast. (June 18-21) Mud flow at El Almendral (40 km east of La Serena) one and a half hour after the onset of rain. Vicuña town was isolated by strong discharge in San Carlos ravine. Main streets of Guanaqueros were destroyed by water and mud flows from the ravines . 15,300 homeless since the rainfall of June 11.	Storm affected a large part of Chile Heavy and persistent rainfalls at Coquimbo and Atacama regions (32°-26°S) -	El Día**: 1997 (June 12-14; 19-24)
21	1997, August (16-18)	38.9 mm (onset at 18hrs, August 16), 19 mm (August 17) and 5 mm (August 18) at La Serena * 15 mm (August 15), No data (August 16), 75.4 mm (August 17) and 31.6 mm (August 18)	~ 2 days	Blocking	2.0 (El Niño)	Torrential rainfall with strong wind (up to 100 km/hr), sometimes intense but not persistent. Roads and bridges cut off by rivers and mud flows isolated towns, flooded houses and damaged agricultural crops. Strong wind brought down trees and caused severe damage in infrastructure, houses and boats. Closure of ports at Los Vilos, Tongoy and Guanaqueros. 50% of boats were destroyed at Guanaqueros.	Storm caused damage from Puerto Montt (42°S) to Coquimbo (30°S) Coquimbo region was most affected.	El Día**: 1997 (August 17-18)
22	2000, June 23-24	29.5 mm (June 23) and 3.7 mm (June 24) at La Serena* 52.1 mm (June 24) at Puerto Oscuro*	~ 3 hrs	Blocking	-0.5 (La Niña)	Strong wind (70-80 kn/hr) destroyed roofs, felled trees, caused a power outage and interrupted water supply in some sectors. Flooded streets. Jaramillo channel almost overflowed Port of Coquimbo closed by strong northwest wind, that caused huge waves. Two million scallops were stranded at Puerto Aldea (50 km south of La Serena)	Strong winds and rainfall affected a large part of Chile Calama and Chuquicamata (22°30'S) were affected by strong wind (90 km/hr) Strong wind at Caldera and Copiapó (27°S) destroyed roofs and dust storm on Panamericana Highway Ports of central Chile closed. Flooding and damage from Talca (35°S) to Rancagua (34°S). 1,692 homeless.	El Día**: 2000 (June 24-25)

Meteorological data extracted from (*) Dirección Meteorológica de Chile and (**) El Día Newspaper
(***) Duration corresponds to the length of rain at La Serena recorded by the newspaper El Día