DR2014076: SUPPLEMENTARY MATERIAL

TABLE SM1 Coordinates of stations in the downstream direction, sediment thickness and grain-size fractions for the three time intervals.

TABLE SM2 Surface sediment discharge and depositional flux for the Escanilla sediment routing system at 10 km intervals in the down-system direction.

SUPPLEMENTARY TEXT
Correlation and recognition of time intervals

Mapping of the sediment routing system fairway

References cited in Supplementary Material

Table SM1: Coordinates of stations in the downstream direction, sediment thickness and grain-size fractions for the three time intervals.

Time interval 1, 41.6 to 39.4 Ma:

Time Interval 1: Sis Paleovalley to Viacamp (Cornudella Formation to Lower Escanilla)											
Stations in the downsystem direction (*x*)											
	Apex	Start	A	B	C	E	N	O	P	Q	V4
x (m)	0	4000	6630	8500	10540	15000	15400	16400	17650	18250	36000
W (m)	1	1	5650	6000	6650	6360	6360	6650	6285	5700	9900
w (m)	1	1	3000	2800	4000	5800	5800	2000	4000	5000	5200
h_1(m)	0	0	12.5	29	30	71	175	90	200	200	82.5
F_{cgl}	0	0	0.5	0.66	0.80	0.62	0.52	0.38	0.40	0.38	0.22
F_{sst}	0	0	0.5	0.34	0.17	0.35	0.48	0.62	0.60	0.62	0.26
F_{fine}	0	0	0	0	0.03	0.03	0	0	0	0	0.52
Error (m)	0	0	1000	1000	1000	1000	1000	1000	1000	1000	1000

Time Interval 1: Gurb-Pobla Paleovalleys to Viacamp (Montsor 1 to Lower Escanilla)							
Stations in the downsystem direction (*x*)							
	Apex	Start	G1	G4	G6	G2	V4
x (m)	0	4000	10250	10450	16600	17000	36000
W (m)	1	1	8000	8000	6500	6500	9900
w (m)	1	1	2700	3725	1500	2150	5200
h_i(m)	0	0	90	65	99	162	82.5
F_{cgl}	0	0	0.56	0.26	0.27	0.22	0.22
F_{sst}	0	0	0.06	0.06	0.07	0	0.26
F_{fine}	0	0	0.39	0.68	0.66	0.78	0.52
Error (m)	0	0	1000	1000	1000	1000	1000

Time Interval 1: Viacamp to Jaca (Lower Escanilla to top Hecho Group-basal Arguis Marls)															
Stations in the downsystem direction (x)															
	V1	V2	LAADC	LA1	LEF	ALig	AEri	Aalm	Amed	AG	HSOr	HAMo	HSal	HSFe	End
x (m)	36500	37800	46000	48700	50700	80200	82600	83000	87500	95200	123800	131350	165000	167000	207500
W (m)	9750	9900	7500	8250	8600	9650	9500	9500	9300	6150	18300	17165	15780	15780	15780
w (m)	3500	6000	6300	6500	5300	3000	5400	5500	5700	4000	7500	10100	9900	9900	9900
h_1(m)	107	76	117	124	81	363	195	215	451	115	322.5	167.5	275	0	0
F_{cgl}	0.13	0.11	0.09	0.19	0.27	0.16	0.17	0.12	0.04	0.03	0	0	0	0	0
F_{sst}	0.29	0.24	0.21	0.23	0.10	0.26	0.49	0.47	0.51	0.33	0.4	0	0	0	0
F_{fine}	0.58	0.66	0.7	0.57	0.63	0.55	0.34	0.41	0.45	0.64	0.6	1	0	1	1
Error (m)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	2000	2000	2000	2000	2000

Time interval 2, 39.4 to 35.7 Ma:

Time Interval 2: Sis Paleovalley to Viacamp (Sis1 Formation to Middle Escanilla)								
Stations in downsystem direction (x)								
	Start	A	B	C	D	E	V4	End
x (m)	0	4000	7500	8500	10540	13300	16400	35000
W (m)	1	1	5650	6000	6650	7500	6650	9900
w (m)	1	1	3000	2800	4500	5300	2000	5200
h_2(m)	0	0	10	27	149	360	40	54.75
F_{cgl}	0	0	1	0.96	0.93	0.75	0.39	0.13
F_{sst}	0	0	0	0.04	0.07	0.25	0.61	0.35
F_{fine}	0	0	0	0	0	0.0	0.00	0.52
Error (m)	0	0	1000	1000	1000	1000	1000	1000

Time Interval 2: Sis Paleovalley to Viacamp (Sis 2 Formation to Middle Escanilla)								
Stations in downsystem direction (x)								
	Start	A	B	C	D	E	V4	End
x (m)	0	4000	7500	8500	10220	13400	14500	35000

W (m)	1	1	3500	4500	3000	3225	2550	9900
w (m)	1	1	1700	1500	1300	1425	2075	5200
h_2(m)	0	0	80	60	70	120	30	54.75
F_{cgl}	0	0	0.95	0.95	0.8	0.82	0.66	0.13
F_{sst}	0	0	0.05	0.05	0.15	0.18	0.33	0.35
F_{fine}	0	0	0	0	0.05	0	0.01	0.52
Error (m)	0	0	1000	1000	1000	1000	1000	1000

Time Interval 2: Gurb-Pobla Paleovalleys to Viacamp (Montsor 2 Formation to Middle Escanilla)								
Stations in downsystem direction (*x*)								
	Start	G1	G4	G3	G6	G2	V4	End
x (m)	0	4000	10250	10450	13440	16620	17000	35000
W (m)	1	1	8000	8000	8900	6500	6500	9900
w (m)	1	1	2600	3600	3350	1500	2150	5200
h_2(m)	0	0	154	120	69	69	161	109.5
F_{cgl}	0	0	0.97	0.56	0.74	0.36	0.45	0.13
F_{sst}	0	0	0.01	0.07	0.09	0.01	0.01	0.35
F_{fine}	0	0	0.02	0.38	0.17	0.62	0.55	0.52
Error (m)	0	0	1000	1000	1000	1000	1000	1000

Time Interval 2: Viacamp to Jaca (Middle Escanilla in Tremp and Ainsa basins to top of Arguis Marls and deltaic Atarés Formation in Jaca basin)														
Stations in downsystem direction (*x*)														
	V1	V2	LAA DC	LAA1	LEF	ALig	AEri	Aalm	Amed	HSOr	HAMo	JSal	JSFe	End
x (m)	36000	37800	46500	48900	50700	81500	84000	84400	85800	123800	131350	165000	167000	207500
W (m)	9750	9900	7000	10000	8400	12000	11000	11000	10000	18300	17165	15780	15780	15780
w (m)	3500	6000	6000	8000	5000	6000	7000	8350	9000	7500	10100	9900	9900	9900
h_2(m)	146	114	174	119	81	231	366	86	144	1015	975	525	1	1
F_{cgl}	0.14	0.18	0.09	0.34	0.2	0.3	0.18	0.34	0.11	0	0	0	0	0
F_{sst}	0.37	0.39	0.26	0.24	0.15	0.26	0.49	0.34	0.46	0.22	0.14	0.29	0	0

F_{fine}	0.49	0.42	0.64	0.41	0.65	0.44	0.33	0.33	0.43	0.78	0.86	0.71	1	1
Error (m)	1000	10000	1000	1000	1000	1000	1000	1000	1000	2000	2000	2000	2000	2000

Time interval 3, 35.7 to 33.9 Ma:

Time Interval 3: Sis Paleovalley to Viacamp (Sis 3 Formation to Upper Escanilla)									
Stations in downsystem direction (*x*)									
	Apex	Start	A	B	C	L	J	G	LAA1
x (m)	0	3000	6630	8500	10540	11360	13300	13900	48900
W (m)	1	1	5650	6000	6650	6650	6500	6500	7600
w (m)	1	1	3000	2800	4000	4800	6400	6400	4400
h_2(m)	0	0	275	170	110	35	90	90	22
F_{cgl}	0	0	1	1	0.95	0.45	0.85	0.85	0.27
F_{sst}	0	0	0	0	0.05	0.5	0.1	0.1	0.23
F_{fine}	0	0	0	0	0	0.05	0.05	0.05	0.5
Error (m)	0	0	1000	1000	1000	1000	1000	1000	1000

Time Interval 3: Sis Paleovalley to Viacamp (Sis 4 Formation to Upper Escanilla)								
Stations in downsystem direction (*x*)								
	Apex	Start	A	B	C	J	G	LAA1
x (m)	0	3000	6630	8500	10540	13300	13900	48900
W (m)	1	1	5650	6000	6560	6500	6500	7600
w (m)	1	1	3000	2800	4500	6400	6100	4400
h_2(m)	0	0	95	50	40	120	75	22
F_{cgl}	0	0	1	1	0.85	1	1	0.27
F_{sst}	0	0	0	0	0.15	0	0	0.23
F_{fine}	0	0	0	0	0	0	0	0.5
Error (m)	0	0	1000	1000	1000	1000	1000	1000

Time Interval 3: Gurb-Pobla Paleovalleys to Viacamp (Montsor 3 Formation to Upper Escanilla)

Stations in downsystem direction (*x*)								
	Apex	Start	G1	G4	G5	G6	G2	LAA1
x (m)	0	3000	10250	10450	11900	16600	17000	48900
W (m)	1	1	8000	8000	7500	6500	6500	7600
w (m)	1	1	2600	3550	1500	1500	1300	4400
h_2(m)	0	0	145	50	101	72	67	44
F_{cgl}	0	0	0.95	0.56	0.95	1	0.91	0.27
F_{sst}	0	0	0.02	0.06	0.05	0	0.04	0.23
F_{fine}	0	0	0.03	0.38	0	0	0.04	0.5
Error (m)	0	0	1000	1000	1000	1000	1000	1000

Time Interval 3: Viacamp to Jaca (Upper Escanilla in Tremp and Ainsa Basins to Lower Campodarbe Group in Jaca Basin)									
Stations in downsystem direction (x)									
	ALig	AEri	JSOr	HAMo	JPLO	JSJdP	JSal	HSFe	End
x (m)	81400	83000	123800	131350	145000	158000	165000	167000	208500
W (m)	9500	9500	16200	16750	16750	15130	15130	15130	15130
w (m)	7500	7200	7950	10370	12840	8500	8600	8600	8600
h_2(m)	465	461	648	825	1000	1000	1183	588	1
F_{cgl}	0.39	0.48	0.16	0	0.01	0	0.01	0	0
F_{sst}	0.32	0.38	0.19	0.38	0.29	0.15	0.42	0.35	0
F_{fine}	0.3	0.14	0.65	0.62	0.71	0.85	0.57	0.65	0
Error (m)	1000	1000	2000	2000	2000	2000	2000	2000	2000

Table SM2 Surface sediment discharge and depositional flux for the Escanilla sediment routing system at 10 km intervals in the down-system direction

Interval 1 Surface sediment discharge km^3/m.y.

	x(km)	Total	Gravel	Sand	Fines
Sis	0	105.3	8.2	24.6	72.5
	10	104.6	7.8	24.5	72.3
	20	101.1	6.6	23.7	70.8
	30	96.4	5.3	22.5	68.6
Gurb	0	140.9	11.0	33.0	97.0
	10	139.9	10.4	32.8	96.7
	20	135.3	8.8	31.8	94.7
	30	128.9	7.1	30.1	91.8
Confluence	40	217.2	10.8	50.4	156.0
	50	212.9	10.2	49.5	153.2
	60	206.2	8.7	48.2	149.3
	70	192.7	5.9	45.0	141.8
	80	172.5	2.0	39.9	130.7
	90	154.6	0.4	31.7	122.6
	100	146.0	0.1	28.0	117.9
	110	130.7	0.0	22.0	108.6
	120	103.5	0.0	11.1	92.4
	130	72.2	0.0	0.2	72.0
	140	54.9	0.0	0.0	54.9
	150	35.6	0.0	0.0	35.6
	160	14.0	0.0	0.0	14.0
	170	0.0	0.0	0.0	0.0

Interval 1 Depositional flux km^3/m.y.

	x(km)	Total	Gravel	Sand	Fines
Sis	0	0.0	0.0	0.0	0.0
	10	0.4	0.2	0.1	0.0
	20	3.3	1.5	1.7	0.0
	30	5.0	1.6	2.4	1.0
Gurb	0	0.0	0.0	0.0	0.0
	10	1.4	0.8	0.1	0.5
	20	4.9	1.3	0.2	3.4
	30	6.1	1.3	0.5	4.2
Confluence	40	8.1	1.7	2.1	4.3
	50	4.3	0.5	0.9	2.8
	60	6.8	1.6	1.2	4.0
	70	13.5	2.8	3.2	7.5
	80	20.2	3.9	5.2	11.1
	90	17.9	1.6	8.2	8.1
	100	8.6	0.2	3.7	4.6
	110	15.4	0.1	6.0	9.3
	120	27.2	0.0	10.9	16.3
	130	31.3	0.0	10.9	20.3
	140	17.3	0.0	0.2	17.2
	150	19.3	0.0	0.0	19.3
	160	21.6	0.0	0.0	21.6
	170	14.0	0.0	0.0	14.0

Interval 2 Surface sediment discharge km^3/m.y.

	x(km)	Total	Gravel	Sand	Fines
Sis	0	343.8	16.1	74.5	253.3
	10	341.9	14.2	74.4	253.2
	20	333.8	9.8	72.3	251.7
	30	326.2	7.7	69.9	248.7
Gurb	0	275.7	12.9	59.7	203.1
	10	274.1	11.4	59.7	203.1
	20	267.7	7.9	58.0	201.8
	30	261.6	6.2	56.0	199.4
Confluence	40	577.7	12.2	122.3	443.2
	50	572.3	11.3	120.7	440.2
	60	566.8	10.0	119.7	437.2
	70	557.4	7.3	117.5	432.6
	80	544.0	3.3	114.1	426.6
	90	530.7	1.0	109.5	420.2
	100	498.6	0.5	101.3	396.8
	110	438.2	0.2	87.4	350.7
	120	349.5	0.0	67.6	281.9
	130	243.7	0.0	46.1	197.6
	140	157.8	0.0	33.0	124.8
	150	86.1	0.0	20.2	65.9
	160	28.3	0.0	7.5	20.8
	170	0.3	0.0	0.0	0.3
	180	0.2	0.0	0.0	0.2
	190	0.1	0.0	0.0	0.1
	200	0.1	0.0	0.0	0.1

Interval 2 Depositional flux km^3/m.y.

	x(km)	Total	Gravel	Sand	Fines
Sis	0	0.0	0.0	0.0	0.0
	10	1.2	1.1	0.1	0.0
	20	9.4	5.2	3.5	0.7
	30	7.3	1.8	3.4	2.1
Gurb	0	0.0	0.0	0.0	0.0
	10	2.3	2.2	0.0	0.0
	20	5.0	2.7	0.2	2.1
	30	6.5	2.0	1.0	3.5
Confluence	40	10.1	1.6	3.6	4.9
	50	5.5	0.9	1.6	3.0
	60	5.4	1.3	1.1	3.0
	70	9.4	2.6	2.2	4.6
	80	13.4	4.0	3.3	6.1
	90	13.3	2.3	4.6	6.3
	100	32.1	0.5	8.1	23.5
	110	60.4	0.3	14.0	46.1
	120	88.7	0.2	19.8	68.8
	130	105.8	0.0	21.5	84.3
	140	85.9	0.0	13.1	72.8
	150	71.7	0.0	12.8	58.9
	160	57.7	0.0	12.7	45.1
	170	28.0	0.0	7.5	20.5
	180	0.1	0.0	0.0	0.1
	190	0.1	0.0	0.0	0.1
	200	0.1	0.0	0.0	0.1

Interval 3 Surface sediment discharge km^3/m.y.

	x(km)	Total	Gravel	Sand	Fines
Sis	0	329.2	47.1	90.2	191.7
	10	324.9	42.9	90.1	191.7
	20	320.3	38.8	89.9	191.5
	30	316.8	35.9	89.6	191.1
	40	313.9	34.0	89.2	190.5
Gurb	0	249.3	35.7	68.3	145.2
	10	246.0	32.5	68.2	145.2
	20	242.6	29.4	68.0	145.0
	30	239.9	27.2	67.8	144.7
	40	237.7	25.8	67.6	144.2
Confluence 1	50	547.4	58.1	156.0	333.0
	60	540.6	55.8	154.1	330.4
	70	528.6	51.3	150.5	326.5
	80	511.3	44.7	145.1	321.3
	90	488.1	35.1	137.3	315.5
	100	455.5	25.1	128.3	301.8
	110	413.0	15.0	118.4	279.2
Confluence 2	120	360.6	5.0	107.6	247.7
	130	400.5	1.4	121.5	277.3
	140	325.6	1.1	95.0	229.1
	150	246.3	0.7	72.7	172.5
	160	163.2	0.6	56.8	105.5
	170	87.7	0.0	30.5	56.9
	180	48.1	0.0	16.7	31.2

Interval 3 Depositional flux km^3/m.y.

	x(km)	Total	Gravel	Sand	Fines
Sis	0	0.0	0.0	0.0	0.0
	10	5.0	5.0	0.0	0.0
	20	4.2	3.8	0.3	0.1
	30	3.5	2.8	0.3	0.4
	40	2.8	1.9	0.3	0.6
Gurb	0	0.0	0.0	0.0	0.0
	10	2.5	2.4	0.1	0.1
	20	3.8	3.5	0.1	0.1
	30	2.7	2.2	0.2	0.3
	40	2.3	1.5	0.3	0.6
Confluence 1	50	4.1	1.7	0.8	1.6
	60	6.8	2.3	1.9	2.6
	70	12.0	4.5	3.6	3.9
	80	17.2	6.6	5.4	5.2
	90	23.2	9.6	7.8	5.8
	100	32.7	10.1	9.0	13.6
	110	42.5	10.0	9.9	22.6
Confluence 2	120	52.3	10.0	10.8	31.5
	130	63.4	7.4	15.7	40.2
	140	74.9	0.3	26.5	48.1
	150	79.3	0.4	22.3	56.6
	160	83.1	0.2	15.9	67.0
	170	75.5	0.6	26.3	48.7
	180	39.6	0.0	13.8	25.7

	190	20.3	0.0	7.0	13.1	190	27.8	0.0	9.7	18.0
	200	4.3	0.0	1.5	2.8	200	16.0	0.0	5.5	10.4
Santa Orasia	120	103.2	3.8	29.6	69.8					

SUPPLEMENTARY TEXT

Correlation and recognition of time intervals:

Sedimentological data were collected in a field campaign in the Gurb, Viacamp and Lascuarre regions, complementing existing sedimentary log data in Sis (Vincent, 1993, 2001), the Ainsa Basin (Bentham et al., 1993; Bentham and Burbank, 1996) and the Jaca Basin (Jolley 1987; Turner, 1990, 1992; Hogan and Burbank, 1996) for the same time-equivalent units. The terrestrial segment of the routing system terminates within the Ainsa Basin for time intervals 1 and 2, and terminates in the Jaca Basin for time interval 3. A significant amount of sediment bypassed the terrestrial segment and was transported into the marine environments of the western Ainsa and Jaca Basins.

The Sis and Gurp-Pobla fan systems acted as the main tributaries for the Viacamp, Lascuarre and Ainsa areas. A far-field dynamic link, or 'teleconnection', with the Jaca Basin is based on studies of Puigdefàbregas (1975), Teixell (1998), Hogan and Burbank (1996) and Costa et al. (2010). In the uppermost Eocene (from 36 Ma onwards, Lower Campodarbe Group, time-interval 3) uplift of the western Pyrenees initiated a contribution to the sedimentary budget from additional paleovalley systems such as represented by the Santa Orasia fan.

Correlation between localities is based on regional paleomagnetic studies undertaken by Hogan and Burbank (1996) and Costa et al. (2010) in the Jaca Basin, Bentham et al. (1992), Bentham and Burbank (1996), Mochales et al. (2012) and Rodriguez-Pinto et al. (2012) in the Ainsa and Tremp basins, and Beamud et al. (2003, 2010) in the proximal paleovalleys and feeder systems of Sis and Gurb. A compilation of all data is given in the thesis of Beamud (2013). We constructed a correlation panel along the depositional fairway of the sediment routing system and subdivided the stratigraphy into 3 time-intervals representing 41.6 to 39.1 Ma, 39.1 to 36.5 Ma and 36.5 to 33.9 Ma. The recognition of time-lines enabling this stratigraphic subdivision is explained below.

Sedimentary graphic logs were constructed from measured sections: bed thickness, lithology, grain size, sedimentary structures, conglomeratic clast lithology, paleocurrent directions, dip and dip-direction were recorded. The typical resolution of logging was 1cm: 1m, since the objective was to capture broad facies relationships, grain-size and facies abundance in the stratigraphic sections in a >200 km-long paleo-sediment routing system. Between 3 and 7 sections were logged in each of 5 areas - Sis, Gurb, Viacamp, Lascuarre and Ainsa. These areas can be confidently linked within the sediment routing system based on provenance results from samples collected and field observations, combined with previously published results. Detrital samples were analysed for Apatite Fission Track (AFT), U/Pb dating of zircons, heavy mineral analysis, inventories of clast lithologies and paleocurrent data. These data are tabulated in the thesis of Michael (2013). For the Sis area and the Ainsa and Jaca basins, detailed sedimentological logs were available from Vincent (1993, 2001), Bentham (1992), Jolley (1987) and Hogan and Burbank (1996).

Recognition of time-lines - top of the Escanilla Formation and time-equivalents: The top of the Escanilla Formation is at the Priabonian-Rupelian boundary, dated as *ca*. 33.9 Ma. The overlying Collegats and Antist Groups (and locally the Senterada Formation) make up the uppermost stratigraphy in all the exposures studied at the Gurb, Sis, Viacamp, and Lascuarre localities in the Tremp-Graus Basin and in the Ainsa Basin. In all these localities, the contact between the underlying units of the Escanilla sediment routing system and the overlying Collegats or Antist units is an erosional and angular unconformity (Whittaker *et al*. 2011; Beamud, 2013), but in the Jaca Basin the boundary is dated by paleomagnetic methods (Hogan and Burbank, 1996) and separates the Lower and Middle Campodarbe Groups without an angular break.

Recognition of time-lines – base of the Escanilla Formation and time-equivalents: The base of the Escanilla Formation in the Ainsa and Tremp basins is placed in the uppermost Lutetian. In the Gurb-Pobla area, Lutetian fan deposits of the Pessonada Group (Pobla Basin) and Espills Formation and Gurb 1-4 units (Gurb escarpment) underlie Escanilla-aged sedimentary rocks, which in turn overlie a strong angular unconformity of millions of years duration. In the Sis paleovalley-fill, the Cajigar Formation directly overlies this unconformity and is overlain by the Escanilla-age Cornudella Formation. The lower boundary of the Escanilla system becomes a paraconformity and marks a transition of facies and stratigraphic architecture in the

Ainsa and Tremp depozones, and is a conformity in the uppermost Hecho Group in the Jaca Basin.

The Escanilla time-equivalent units in the Gurb-Pobla area are part of the Pallaresa Group (Mellere & Marzo, 1992; Mellere, 1993). On the borders of the Gurb paleovalley, the Escanilla-age Montsor units of the Pallaresa Group onlap and overlie with a strong angular unconformity the upper Maastrichtian-lower Paleocene Garumnian units, part of the Tremp Formation. The Pallaresa Group north of the Sant Cornelli anticline unconformably overlies older, tectonically deformed Santonian-Campanian strata of the Vallcarga and Arén Sandstone units. Further to the north, Montsor units of the Pallaresa Group overlie Upper Cretaceous platform carbonate units.

In the Sis paleovalley the time-equivalent units of the Escanilla Formation are part of the Cornudella and Sis Formations (Beamud et al., 2003). These units unconformably locally overlie folded and thrusted pre-paleovalley strata consisting of parts of the Vallcarga, Arén and Tremp Formations and part of the older basal Mesozoic carbonate platform units (Vincent, 2001).

In the Viacamp region in the Tremp Basin the Escanilla Formation overlies with a disconformity and angular unconformity the underlying lower to middle Eocene Montañana Group, including the distinctive Castissent Formation (Nijman, 1998). The contact can be recognized as a facies transition from meandering alluvial deposits and delta plain deposits of the Montañana Group to a more dominantly braided style of deposition in the Escanilla Formation. Similar braided deposits in the basal Escanilla Formation are found in the neighboring Lascuarre locality and in the Ainsa Basin. Based on field mapping and cross-sections in the Lascuarre and Viacamp regions, Nijman (1998) correlated the Capella/Perarrua Formation with the upper Montañana Group, which in turn is overlain by the Escanilla Formation in both the Lascuarre and Viacamp localities. At Lascuarre, the Escanilla Formation overlies the tide-influenced delta plain sediments of the Capella Formation (Cuevas Gonzalo, 1983), comprising part of the upper Montañana Group. The base of the Escanilla at Lascuarre has been interpreted at the level of a 5-20 m-thick limestone unit locally known as the ‘Lower Escanilla Limestone’ (Bentham et al., 1993), which is dated in the uppermost Lutetian and at or near the base of zone C19 (41.6 Ma). This dated marker bed gives the basal-time line for the Escanilla paleo-sediment routing system. At Viacamp, this marker bed is thought to coincide with the Viacamp "Lower Limestone" (Cuevas Gonzalo, 1983; Nijman, 1998), which is situated stratigraphically just above the unconformity between the Escanilla Formation and the underlying Montañana units.

In the Ainsa Basin, the Escanilla Formation overlies the Sobrarbe Formation deltaic deposits, which in turn overlie the Hecho Group turbidites. The contact between the two formations has been mapped and dated by Bentham et al. (1993) and Bentham and Burbank (1996) and is contemporaneous with the marker beds in Viacamp and Lascuarre in the Tremp Basin.

In the Jaca Basin, the basal time-line is picked at the base of zone C19 and is part of the uppermost Hecho Group turbidites (Hogan and Burbank, 1996). The lowermost Escanilla age-equivalent units are conformable with the underlying older strata.

Recognition of time-lines – internal subdivision of the Escanilla Formation and time-equivalents: The recognition of further time-lines within the Escanilla paleo-sediment routing system allows its evolution over time to be evaluated. These time-lines are based primarily on scarce magneto-stratigraphic data following guidelines proposed by Beamud et al. (2003, 2010), Bentham & Burbank (1996) and Hogan and Burbank (1996), and are those used by Bentham and Burbank (1996) and Hogan and Burbank (1996) to subdivide the Formation into Lower, Middle and Upper Escanilla in the Ainsa Basin and time-equivalent stratigraphy in the Jaca Basin. The time-equivalent units in the Jaca Basin are the uppermost Hecho Group, Arguis Marls, Atarés Formation and Lower Campodarbe (Jolley, 1987; Hogan and Burbank, 1996; Costa et al., 2010). For this study the proposals of the magnetostratigraphic studies listed above were adopted after shifting and correcting the absolute ages according to the latest magnetozones proposed by Gradstein et al. (2004).

Correlative sedimentological changes or trends were recognized across the Escanilla paleo-sediment routing system, in order to improve and complete the correlation in localities where paleomagnetic data are incomplete (such as the Sis paleovalley) or absent (as at Viacamp). In addition to the recognition of these sedimentological changes, provenance trends were used to improve the correlation in regions with limited data (e.g. Viacamp). Sedimentological changes were defined from grain-size and facies trends on measured sedimentological sections from the proximal to the distal regions. The grain-size data from logs were sampled at a constant interval of 1 m, which is the average bed thickness in the Escanilla Formation, and then smoothed using 9- and 11-point moving averages. Sedimentary cycles were then compared between stations to create the correlation panels. In addition to grain-size curves, lacustrine limestone beds were particularly useful as marker beds. These techniques improve on previous correlations, which were based on linear interpolations between magneto-stratigraphic time-lines.

The time-line at the top of time-interval 1 marks the initial deposition of conglomerates of the Sis Member 1 in the Sis paleovalley and deposition of Montsor 1 conglomeratic units in the Gurb-Pobla area. The event signifies the initiation and establishment of the alluvial fans in the Sis paleovalley and also coincides with a correlative field-wide conglomeratic unit recognized and mapped by Bentham in both the Ainsa and Tremp Basins that subdivides Lower and Middle Escanilla Formation. In the Jaca Basin, this time-line is picked just above the deposition of the Sabiñanigo Sandstones (Jolley 1987; Hogan and Burbank 1996). This time-line is at approximately 39.1 Ma and coincides with just above the end of the first normal polarity of zone C18.

The time-line at the top of time interval 2 is marked by the full continentalisation of the Jaca Basin and uplift of the western Pyrenees (Teixell, 1998; Costa et al., 2010). This coincides with the end of deposition of the Belsué-Atarés Formation and the transition to the fully fluvial, easterly sourced Lower Campodarbe Formation. This time-line coincides with the second basin-wide conglomeratic unit in the Ainsa Basin and a conglomeratic interval at the Lascuarre locality. In Gurb, a small break in the cliff of amalgamated conglomerates is recognizable, associated with the deposition of a few metres of fine overbank deposits subdividing Montsor 2 and Montsor 3 units (Mellere, 1993; Duller et al., 2010; Beamud et al., 2010; Whittaker et al., 2011). In the Sis paleovalley this event is expressed as a change in the style of deposition of the alluvial fan deposits from a conglomeratic cliff-forming wall of Sis 2 Member to the Sis 3 and 4 units, which are slope-forming but comprise very conglomeratic (*ca*. 90% gravel) alluvial fan deposits (Vincent, 2001). In both Ainsa and Lascuarre, the time-line is recognized as an increase in overbank fines and the deposition of relatively thick lacustrine limestones above alluvial conglomerates. The lacustrine limestone and overbank deposits have been correlated with the “upper Viacamp limestone”, which caps the Escanilla Formation in the Viacamp region just below the unconformity with the Antist/Collegats unit. The time-line at the top of time interval 2 is dated at the boundary between zones C17 and C16 at approximately 36.5 Ma.

In contrast to successions in the Gurb, Ainsa and Jaca Basin regions, where there are good age constraints from paleomagnetic data, in the Sis paleovalley, Lascuarre and Viacamp these data are incomplete or absent and therefore additional evidence is needed to place stratigraphic time-lines in these localities. In both the Sis and Lascuarre regions, paleomagnetic data only constrain the top and bottom of time interval 1, and the top of time interval 3 is taken to be the boundary and regional unconformity between Sis member 4 or Escanilla Formation and the Antist/Collegats Group in Sis paleovalley at the Lascuarre locality respectively. Consequently, the time-line at the top of time interval 2 needs to be identified.

In the Viacamp region, where there are no age constraints, time-lines delimiting the Escanilla Formation are based on the recognition of unconformities in the Escanilla time-equivalent succession. The internal time-lines are based on sedimentological (e.g. the presence of the upper Viacamp limestone) and geochronological, thermochronological and petrological criteria (U/Pb geochronology, apatite fission track analysis, petrological trends). The additional data that helped the recognition of time intervals in the Viacamp, Lascuarre and Sis regions are given below.

The time-line at the top of time interval 2 in the Sis paleovalley-fill has been picked between the Sis 2 and Sis 3 Members, based on a dramatic change of provenance signals on either side of that boundary (Vincent, 2001; Michael, 2013). This change has been recorded in all the provenance tools used in this study: petrological data of clast lithologies, heavy mineral data, apatite fission track ages and U/Pb data. A dramatic change is observed in both heavy mineral abundance and the distribution of

U/Pb ages from Sis 1 and Sis 2 (time interval 2) to Sis 3 and 4 members (time interval 3) combined with an absence of granitic clasts in Sis 4 Member (Vincent, 2001; Michael, 2013). All the above indicators suggest a change in provenance of the ancient Sis fan system. A dramatic increase in abundance of epidote group heavy minerals coincides with an increase in the proportion of old-aged zircons from both the Ediacaran and Cadomian events (Whitchurch et al., 2011) and older 1 - 2 billion year-old zircons, which are absent in time intervals 1 and 2. This link between the increase in epidote group heavy minerals and old polycyclic zircons is also found in the Lascuarre region (see below). In addition to the signals discussed above, apatite fission track data (Beamud et al., 2010; Michael, 2013) reveal differences between the three time intervals in their central ages, specifically an increase of AFT central ages in time interval 2 recorded from samples collected from Sis 1 and Sis 2 members and a decrease of those ages in Sis 3 and 4 members, which we assign to time interval 3.

In the Lascuarre locality, a greater portion of the Bartonian-Priabonian interval has been sampled and dated (Bentham and Burbank, 1996) than in the Sis paleovalley-fill. These additional data give confidence in constraining the time-line at the top of time interval 2 in the Lascuarre region. In contrast to the Sis paleovalley, at Lascuarre the provenance signals are less sharp due to the mixing between the various source regions and cannibalization of underlying units from the flanks of the basin. The correlation at Lascuarre is based on three observations: a) the proposed time-line at the top of time interval 2 coincides with the end of deposition of a 100 m-thick conglomeratic interval culminating a coarsening-up trend; b) the next cycle begins with a 20 m-thick layer of overbank siltstones and mudstones interfingered with beds of lacustrine limestone. This sedimentological signal is similar to that observed in the Ainsa sections where there is a similar increase in limestone beds above the correlative time-line; c) the paleomagnetic record (Bentham and Burbank, 1996) enables the top of time interval 2 to be placed approximately at the boundary of zones C17 and C16 (Gradstein et al., 2004) consistent with its position in other outcrop localities (Ainsa and Jaca). There are additional petrological indicators for defining time interval 3 in the Lascuarre section. The conglomeratic units of time interval 3 are more polymictic and show an increase in the relative abundance of Devonian and Triassic clasts compared to the underlying time interval, as reported for Montsor 3 in the Gurb and Pobla localities (Whittaker et al., 2011). Mineralogically, there is an increase in epidote group minerals, paralleling the trends in the Sis paleovalley-fill.

The Viacamp sections are the most problematic and uncertain in terms of recognizing time-lines. Internal time-lines are based solely on sedimentological, petrographical and U/Pb age data. The Escanilla time-equivalent interval at Viacamp is subdivided into 3 units: a conglomeratic lower unit, a coarsening-up middle unit, and a third unit comprising mostly overbank fines, crevasse splays and lacustrine limestone units. We correlate this younger limestone-rich unit with the limestone units deposited above the base of time interval 3 in both the Ainsa and Lascuarre localities. Following this interpretation, a significant portion of time interval 3 has been eroded prior to the deposition of the Antist/Collegats Group, as also occurs at the Lascuarre locality. This has the effect of underestimating sediment volumes in time interval 3. The boundary between time intervals 1 and 2 is placed at the boundary between two units with distinct differences in detrital zircon U/Pb age distributions and apatite fission track central ages, even though they have very similar clast lithological characteristics and they are both polymictic. A similar change in U/Pb ages and AFT central ages is reported by Beamud et al. (2010) from the Sis and Pobla regions at the level of the boundary between time intervals 1 and 2.

Mapping of the sediment routing system fairway:

The fairway shows the spatial distribution of the predominantly erosional, transportational and depositional zones of the sediment routing system. It is based on existing geological maps (Instituto Cartográfico de Cataluña, Instituto Geológico y Minero de España, Puigdefàbregas (1975), Vincent (1993, 2001), Bentham et al. (1993), Labourdette and Jones (2007), Cuevas Gonzalo (1983), ASTER Digital Elevation Models, our own geological field observations and subsurface data acquired from IGME. Data were collected for the following parameters:

x (m) Down-system distance from the point source of sediment (apex of fan)

W m) Half-width of fairway at a given station

w (m) Orthogonal distance of log locality from nearest edge of sediment routing system fairway

h_i (m) Thickness of the time interval (i = 1 to 3) at the station

F_{cgl} Percentage (fraction) of conglomerate in sedimentary log at a station

F_{sst} Percentage (fraction) of sandstone at a station

F_{fine} Percentage (fraction) of fines (finer than sand and limestones) at a station

Cross-sectional areas were calculated using simplified geometric shapes (e.g. triangle, rectangle, isosceles trapezium) and subdivided according to size fraction (F_g, F_s, F_f). Interpolation between localities allowed depositional volumes subdivided by size fraction to be estimated in the down-system direction. The results presented here are based on the isosceles trapezium approximation, which is believed to be the closest geometrical shape to the Escanilla Formation and age-equivalents and is easily implemented.

The percentage of a grain-size fraction making up the stratigraphy as a function of down-system distance shows the overall downstream fining over the 210 km length of the paleo-sediment routing system. The total volumes occupied by each grain-size fraction give the total sediment grain-size mix and the total volume of sediment released by upstream catchments. Since sediment cascades from source to sink, the volumetric profiles also make possible the estimation of the depositional fluxes at each station and the remaining surface flux. In this way, the transfer of surface sediment fluxes from station to station becomes evident.

The sediment routing system fairway is reconstructed based on field observations largely from paleoflow data, which reveal the predominant slopes and basin gradients, sedimentological data including sedimentary facies and grain-size signals, clast lithologies, and laboratory results from heavy mineral analysis and U/Pb dating on detrital zircons. The linkage between stations is also tested with structural and seismic studies to see the interconnectivity between the various outcrop localities. The mapping of the sediment fairway is based largely on the structurally confined Ainsa and Tremp basins. In the Jaca Basin, however, the extent of the sediment routing system fairway is estimated from palinspastically reconstructed and balanced cross-sections (Jolley, 1987).

The southerly extent of the Escanilla system in the Tremp Basin is delimited in our study by the position of the Montsec thrust. However, upper Eocene sedimentary rocks are missing south of the present trace of the Montsec thrust. We argue that (1) the Montsec is known to have produced a topographic barrier by the Paleocene-early Eocene, and continued to do so into the mid-late Eocene; (2) paleocurrents in the Escanilla Formation of the south-central unit are generally westwards, except where affected by synsedimentary growth of oblique structures such as the Mediano High; and (3) Escanilla-aged sedimentary rocks thin onto the northern flank of the Montsec structure. We therefore map the extent of the Escanilla paleo-sediment routing system as shown in Figure 3 in the Main Text, while acknowledging that the southern limit is inexact, which may result in an underestimation of the total sediment volume in the paleo-sediment routing system.

REFERENCES CITED IN SUPPLEMENTARY MATERIAL

Beamud, E., 2013, Paleomagnetism and thermochronology in Tertiary syntectonic sediments of the south-central Pyrenees: Chronostratigraphy, kinematics and exhumation constraints. PhD, University of Barcelona, 250pp.

Beamud, E., Garcés, M., Cabrera, L., Muñoz, J.A. and Almar, Y., 2003, A new middle to late Eocene continental chronostratigraphy from NE Spain: Earth and Planetary Science Letters, v. 216, p. 501-514.

Beamud, E., Munoz, J.A., Fitzgerald, P.G., Baldwin, S.L., Garcés, M., Cabrera, L. and Metcalf, J.R., 2011, Magnetostratigraphy and detrital apatite fission track thermochronology in syntectonic conglomerates: constrains on the exhumation of the south-central Pyrenees: Basin Research, v. 23, p. 309-331.

Bentham P., 1992, The tectonic stratigraphic development of the western oblique ramp of the South-Central Pyrenean Thrust system, north Spain: Unpublished PhD thesis, *University of Southern California*, pp. 253.

Bentham, P. A., Talling, P. J., and Burbank, D. W., 1993, Braided stream and flood-plain deposition in a rapidly aggrading basin: the Escanilla formation, Spanish Pyrenees: *in* Geological Society London, Special Publication, v. 75, p.177-194, doi:10.1144/GSL.SP.1993.075.01.11.

Bentham, P.A., Burbank, D. W. and Puigdefabregas, C., 1992, Temporal and spatial controls on alluvial architecture in an axial drainage system, Upper Eocene Campodarbe Group, southern Pyrenean foreland basin, Spain: Basin Research, v. 4, p. 335-352.

Bentham, P. and Burbank, D.W., 1996, E13 chronology of Eocene foreland basin evolution along the western margin of the South-Central Pyrenees, *in* P. F. Friend & C. J. Dabrio (Eds.), Tertiary Basins of Spain: the stratigraphic record of crustal kinematics, Cambridge University Press, p. 144-152.

Costa, E., Garcés, M., López-Blanco, M., Beamud, E., Gómez-Paccard, M. and Larrasoaña, J.C., 2010, Closing and continentalization of the South Pyrenean foreland basin (NE Spain): magnetochronological constraints: Basin Research, v. 22, p. 904-917, doi:10.1111/j.13652117.2009.00452.x.

Cuevas-Gonzalo, M. C., 1983, Sedimentary facies and sequential architecture of tide-influenced alluvial deposits, an example from the middle Eocene Capella Formation, South-Central Pyrenees, Spain: *Geologica Ultraiectina*, no. 61 (PhD thesis).

Duller, R.A, Whittaker, A.C., Fedele, J.J., Springett, J., Smithells, R. and Allen, P.A., 2010, From grain size to tectonics: Journal of Geophysical Research – Earth Surface, v. 115, F03022, doi:10.1029/2009JF001495.

Gradstein, F.M., Ogg, J.G. and Smith, A., 2004, A Geologic Time Scale 2004, Cambridge University Press, Cambridge, 589pp.

Hogan, P. and Burbank, D., 1996, E14 Evolution of the Jaca piggyback basin and emergence of the External Sierra, southern Pyrenees: In: P. F. Friend & C. J. Dabrio (Eds.), Tertiary Basins of Spain: the stratigraphic record of crustal kinematics, Cambridge University Press, p. 144-152.

Jolley, E.J., 1987, Thrust tectonics and alluvial architecture of the Jaca Basin, Southern Pyrenees. (unpublished PhD, University of Wales).

Labourdette, R., & Jones, R.R., 2007. Characterization of fluvial architectural elements using a three-dimensional outcrop data set: Escanilla braided system, South-Central Pyrenees, Spain: Geosphere, v. 3, p. 422. doi:10.1130/GES00087.1.

Mellere, D., 1993, Thrust-generated, back-fill stacking of alluvial fan sequences, south-central Pyrenees, Spain (La Pobla de Segur Conglomerates): *in* Tectonic Controls and Signatures in Sedimentary Successions (ed. by L.E. Frostick and R.J. Steel), Special Publication International Association Sedimentologists, v. 20, p. 259-276.

Mellere, D. & Marzo, M., 1992, Los depósitos aluviales sintectónicos de la Pobla de Segur: alogrupos y su significado tectonoestratigráfico: Acta Geologica Hispanica, v. 27, p.145-159.

Michael, N.M., 2013, Functioning of an ancient sediment routing system, the Escanilla Formation, south-central Pyrenees: PhD, Imperial College London.

Mochales, T., Casas, A.M., Pueyo, E.L. & Barnolas, A.,, 2012, Rotational velocity for oblique structures (Boltaña anticline, southern Pyrenees): Journal of Structural Geology, v. 35, p. 2-16.

Nijman, W., 1998, Cyclicity and basin axis shift in a piggyback basin: towards modelling of the Eocene Tremp-Ager Basin, South Pyrenees, Spain. *Geological Society, London, Special Publications*, v. 134(1), p. 135-162, doi:10.1144/GSL.SP.1998.134.01.07.

Puigdefábregas, 1975, La sedimentacion molásica en la cuenca de Jaca: Pirineos, v. 104, pp. 188.

Rodriguez-Pintó, A., Pueyo, E.L., Serra-Kiel, J., Samsó, J.M., Barnolas, A and Pocoví, A., 2012, Lutetian magnetostratigraphic calibration of larger foraminifera zonation (SBZ) in the southern Pyrenees: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 333-334, p.107-120.

Teixell, A., 1998, Crustal structure and orogenic material budget in the west central Pyrenees: Tectonics, v. 17, p. 395- 406.

Turner, J. P., 1990, Structural and stratigraphic evolution of the West Jaca thrust-top basin, Spanish Pyrenees: Journal of the Geological Society, v. 147(1), p. 177-184. doi:10.1144/gsjgs.147.1.0177 (2)

Turner, J.P. 1992. Evolving alluvial stratigraphy and thrust front development in the West Jaca piggyback basin, Spanish Pyrenees. Journal of the Geological Society, 149: 51-63, doi:10.1144/gsjgs.149.1.0051.

Vincent S.J., 1993, Fluvial palaeovalleys in mountain belts: an example from South-Central Pyrenees: Unpublished PhD thesis, University of Liverpool.

Vincent, S.J., 2001, The Sis palaeovalley: a record of proximal fluvial sedimentation and drainage basin development in response to Pyrenean mountain building: Sedimentology, v. 48, p. 1235-1276.

Whitchurch, A., Carter, A., Sinclair, H.D., Duller, R., Whittaker, A.C. and Allen, P.A., 2011, Sediment routing systems and the lag-time concept: A case study from the southern Pyrenees: American Journal of Science, v. 311, doi:10.2475/04.2011.00.

Whittaker, A.C., Duller, R.A., Springett, J., Smithells, R., Whitchurch, A.L. and Allen, P.A., 2011, Decoding downstream trends in stratigraphic grain-size as a function of tectonic subsidence and sediment supply: Bulletin Geological Society America, v. 123, p. 1363-1382, doi:10.1130/B30351.1.