A Chinese imprint in insoluble pollutants recently deposited in central Greenland as indicated by lead isotopes

Aloys J.-M. Bory[1†*], Wafa Abouchami[2], Stephen J.G. Galer[2], Anders Svensson[3], John N. Christensen[4] and Pierre E. Biscaye[1]

[1]*Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY 10964, USA.*
[2]*Max Planck Institute for Chemistry, 55128 Mainz, Germany.*
[3]*Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen, Denmark.*
[4]*Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA.*
[†]*Present address: Université Lille 1, UMR-CNRS Géosystèmes 8217, 59655 Villeneuve d'Ascq cedex, France.*
[*]*Corresponding author: aloys.bory@univ-lille1.fr*

Supplementary information

6 pages (including the cover sheet)
Figures S1 to S4 and Table S1

Figure S1. Sketch map of Greenland showing the NorthGRIP ice camp location (this study) as well as the ACT2 site *(3)* and Summit *(8, 33)*, shown for reference.

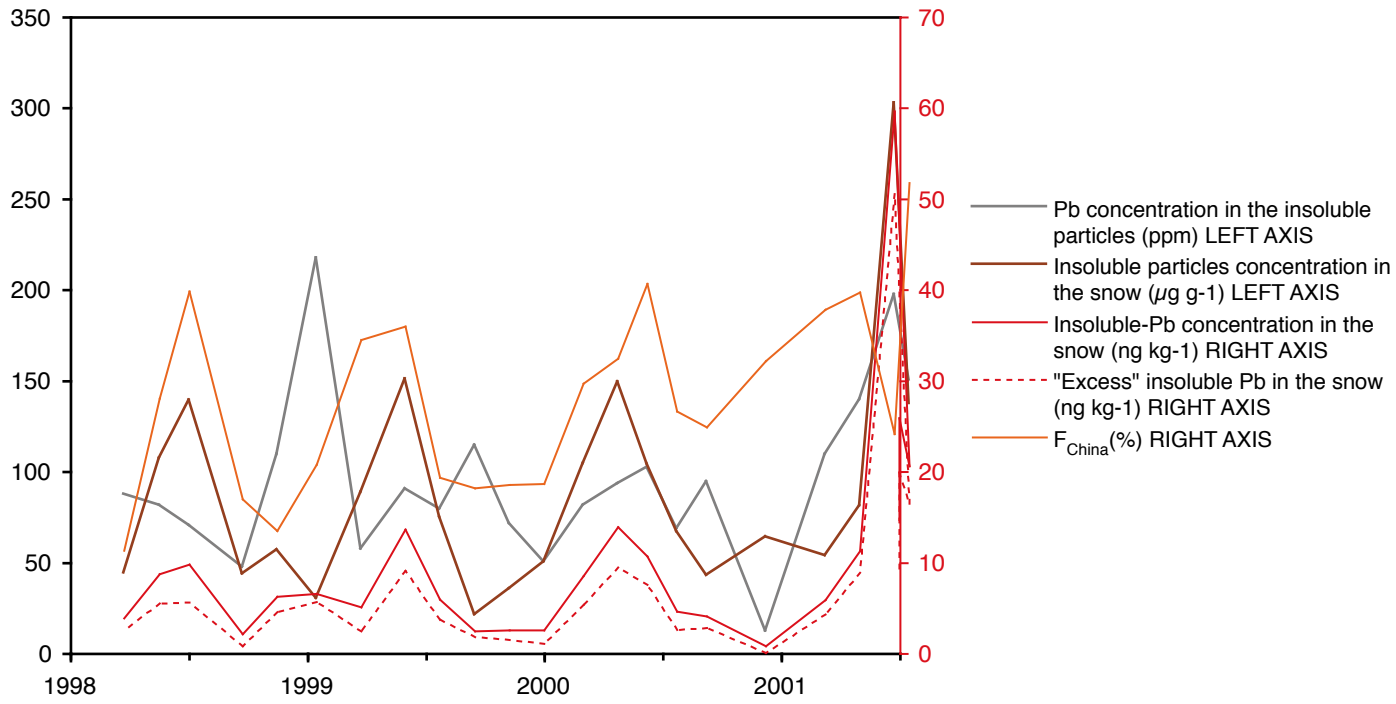

Figure S2. Estimates of lead concentration (ppm) in the insoluble particulate matter deposited at NorthGRIP, insoluble particulate matter concentration (µg.kg^{-1}) and insoluble lead concentration in the snow (ng.kg^{-1}) over the 1998-2001 period, together with calculated F_{China} (%). "Excess" insoluble Pb, defined as "non-dust" Pb and estimated assuming a theoretical Pb dust content of 30 ppm *(18)* and with the approximation that the dust weight was equal to the total insoluble particles weight *(9)*, is also shown.

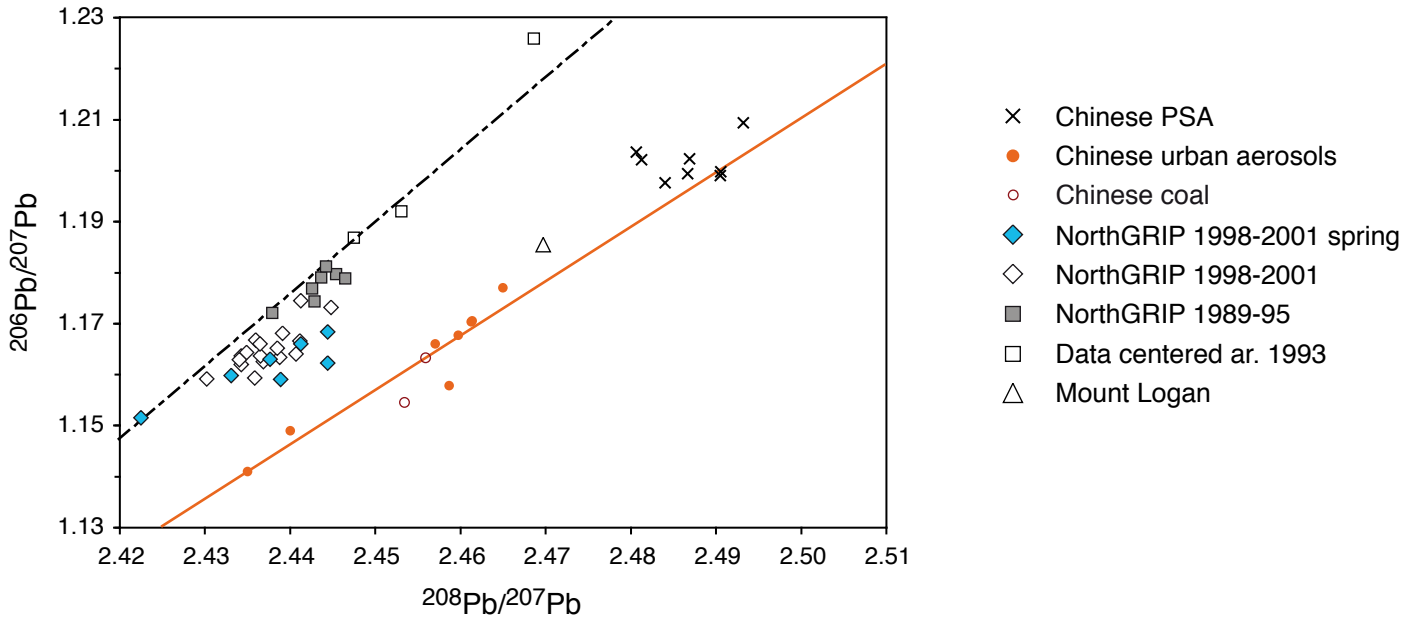

Figure S3. $^{206}Pb/^{207}Pb$ versus $^{208}Pb/^{207}Pb$ of insoluble particles at NorthGRIP and Mount Logan against lead isotopic composition of Chinese PSA samples (this study and Biscaye et al. *(6)*), urban aerosols *(13, 21)* and coal samples *(42, 43)*. NorthGRIP sample "baseline" (dash line) and the regression line for Chinese urban aerosols (orange line) are also shown.

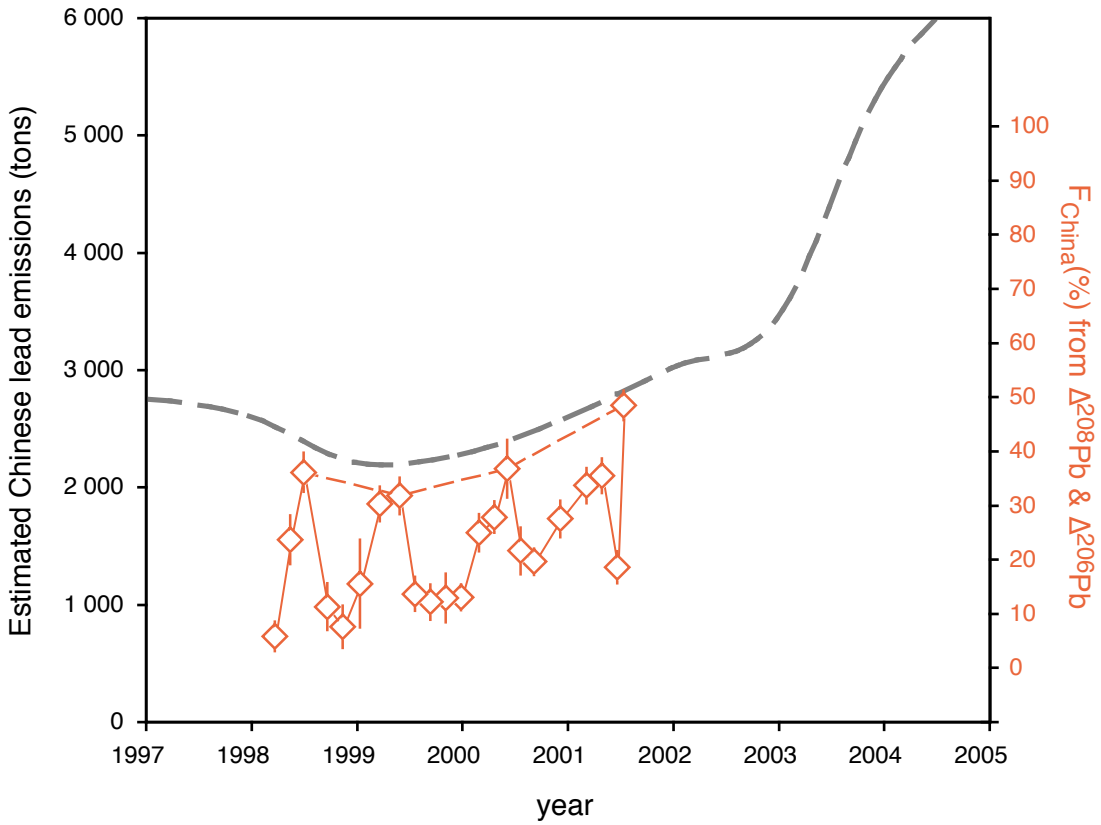

Figure S4. F_{China} (%; from $\Delta^{208}Pb$ and $\Delta^{206}Pb$ calculation –see section 3.3) over the 1998-2001 period together with Pb emissions from coal consumption and ore smelting in China estimated by Li et al. *(41)*.

Table S1. Lead isotope ratios and Pb content in insoluble material extracted from snow-pits at NorthGRIP and Mount-Logan as well as in PSA samples from the China.

	Attempted stratigraphy from ∂180 measurements [Bory et al., 2002; 2003a]	206Pb/204Pb	±2s	207Pb/204Pb	±2s	208Pb/204Pb	±2s	Pb content in the insoluble particles* ppm	Insoluble particle content in the snow** µg.kg^{-1}	Insoluble Pb content in the snow ng.kg^{-1}	"Excess" (non-dust) insoluble Pb*** ng.kg^{-1}
Snow-pit samples											
NorthGRIP. Greenland (75.1°N. 042.3°W; 2,959m.a.s.l.)											
1989-95 time series											
NGDS 2	early 1995	18.318	0.006	15.629	0.008	38.103	0.023	n.d.	8	n.d.	n.d.
NGDS 3	1994	18.454	0.007	15.643	0.009	38.253	0.024	n.d.	7	n.d.	n.d.
NGDS 4	late 1993	18.585	0.007	15.659	0.008	38.326	0.024	n.d.	3	n.d.	n.d.
NGDS 5	late 1992/early 93	19.277	0.006	15.725	0.008	38.819	0.023	n.d.	10	n.d.	n.d.
NGDS 6	early 1992	18.699	0.006	15.687	0.008	38.482	0.024	n.d.	20	n.d.	n.d.
NGDS 7	late 1991	18.457	0.007	15.654	0.009	38.254	0.024	n.d.	16	n.d.	n.d.
NGDS 8	late 1990/early 91	18.416	0.006	15.648	0.008	38.222	0.023	n.d.	7	n.d.	n.d.
NGDS 9	1990	18.356	0.007	15.631	0.009	38.184	0.024	n.d.	17	n.d.	n.d.
NGDS 10	late 1989	18.425	0.006	15.630	0.008	38.239	0.023	n.d.	24	n.d.	n.d.
NGDS 11	early 1989	18.483	0.010	15.649	0.011	38.249	0.029	n.d.	1	n.d.	n.d.
1998-2001 time series											
NGS1	spring/summer 2001	17.9632	0.0021	15.5992	0.0024	37.7884	0.0075	82	178	14.6	9.3
NGS2	spring/summer 2001	18.1600	0.0019	15.6245	0.0023	38.1926	0.0074	130	199	25.8	19.9
NG1	spring/summer 2001	18.1039	0.0019	15.6191	0.0023	38.0933	0.0074	150	137	20.5	16.4
NG2	spring 2001	18.1042	0.0019	15.6094	0.0025	37.9786	0.0080	197	302	59.5	50.5
NG3	winter/spring 2001	18.1078	0.0021	15.6193	0.0027	38.0462	0.0086	139	81	11.2	8.8
NG4	winter 2000-2001	18.1749	0.0022	15.6227	0.0028	38.1001	0.0090	109	53	5.8	4.2
NG5	autumn 2000-2001	18.1571	0.0035	15.6185	0.0033	38.0600	0.0089	12	64	0.8	[<0]
NG6	summer/autumn 2000	18.1492	0.0016	15.6198	0.0021	38.0223	0.0068	94	43	4,0	2.7
NG7	summer 2000	18.1740	0.0029	15.6175	0.0037	38.0521	0.0121	68	67	4.5	2.5
NG8	spring 2000	18.1796	0.0036	15.6172	0.0046	38.1165	0.0148	102	104	10.6	7.5
NG9	winter/spring 2000	18.1611	0.0020	15.6154	0.0025	38.0647	0.0080	93	149	13.8	9.4
NG10	winter 1999-2000	18.2007	0.0023	15.6198	0.0030	38.0891	0.0097	81	104	8.4	5.3
NG11	autumn/winter 1999-2000	18.1747	0.0017	15.6186	0.0021	38.0196	0.0066	50	50	2.5	1,0
NG12	autumn 1999-2000	18.1847	0.0030	15.6181	0.0038	38.0281	0.0125	71	35	2.5	1.4
NG13	summer/autumn 1999	18.1016	0.0031	15.6167	0.0030	37.9520	0.0086	114	21	2.4	1.8
NG14	summer 1999	18.1608	0.0022	15.6160	0.0027	38.0099	0.0086	79	74	5.9	3.6
NG15	spring 1999	18.2085	0.0022	15.6162	0.0029	38.1230	0.0095	90	151	13.5	9,0
NG16	winter/spring 1999	18.2206	0.0023	15.6189	0.0028	38.1279	0.0090	57	88	5,0	2.4
NG17	winter 1998-99	18.2414	0.0055	15.6157	0.0070	38.0882	0.0230	217	30	6.5	5.6
NG18	autumn/winter 1998	18.2201	0.0042	15.6155	0.0038	38.0388	0.0105	109	57	6.2	4.5
NG19	summer/autumn 1998	18.2038	0.0030	15.6121	0.0037	38.0386	0.0120	47	43	2,0	0.7
NG21	spring/summer 1998	18.2480	0.0027	15.6178	0.0032	38.1761	0.0102	70	139	9.7	5.6
NG22	spring 1998	18.3321	0.0032	15.6255	0.0041	38.2015	0.0132	81	107	8.7	5.5
NG23	winter/spring 1997-98	18.3521	0.0020	15.6259	0.0025	38.1470	0.0080	87	44	3.8	2.5
Mount Logan (King Col), Canada (60.6°N. 140.6°W; 4,150m.a.s.l.)											
April 2001											
KC [Zdanowicz et al., 2006]		18.5006	0.0039	15.6061	0.0048	38.5425	0.0157				
Mineral dust potential source areas (PSA)											
Takla Makan, China											
LDEO PSA 251-8		18.7930	0.0036	15.6762	0.0045	39.0438	0.0148				
LDEO PSA 302-5		18.8335	0.0056	15.6695	0.0070	38.8816	0.0233				
LDEO PSA 302-6		18.9593	0.0031	15.6792	0.0037	39.0929	0.0121				
LDEO PSA 302-7		18.8554	0.0047	15.6681	0.0059	38.8689	0.0194				
Inner-Mongolia, China											
LDEO PSA 305-7		18.8033	0.0039	15.6750	0.0048	39.0409	0.0159				

*Estimated from total Pb yield after chemical separation (measured by TIMS) divided by the amount of digested particulate matter.
**Estimated by dividing the weight of the dry insoluble particulate matter by the amount of melted snow. which was measured in the field [Bory et al., 2002].
***Estimated assuming a theoretical Pb dust content of 30 ppm [Svensson. 1998] (with the approximation that the dust weight was equal to the total insoluble particles weight [Drab et al., 2002]).