KILABO AND BENSOUR, TWO LL6 CHONDRITE FALLS FROM AFRICA WITH VERY SIMILAR MINERALOGICAL COMPOSITIONS BUT DIFFERENT COSMIC-RAY EXPOSURE HISTORIES.

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Introduction: In 2002 two meteorites fell within five months of each other in Africa. The first meteorite, Bensour, was reported to have fallen on February 11th along the Algerian/Moroccan border. Five months later on July 21st a second observed fall, Kilabo, was recovered from northern Nigeria. This in itself is certainly not unusual, but the fact that both meteorites were classified as LL6's and are similar in appearance raised some intriguing questions about their origin. In Cole and Sipiera (2003) [1] they suggested that Bensour and Kilabo may belong to the same meteoroid stream based on the timing of the falls, their similar petrography and fayalite compositions. An alternate hypothesis suggests that these meteorites may have originated from the same impact event on the LL chondrite parent body, but traveled in different orbits which coincidentally brought them to Earth at about the same place and time. To address these possibilities the meteorites were analyzed for their cosmogenic nuclides and metallic compositions.

Analytical Procedures: The metal composition analyses were performed by Kees Welten at the Space Science Laboratory at the University of California at Berkeley. The radionuclides were chemically separated at Berkeley and measured at the Lawrence Livermore National Laboratory. Noble gas analyses were performed by Ludolf Schultz at the Max Planck Institut für Chemie in Mainz. Earlier electron microprobe analyses of the primary silicate phases were made by Kevin Cole at the University of Illinois at Chicago.

Results: The metal fractions from the Bensour and Kilabo LL6 chondrites are very similar in composition, showing unusually high Ni and Co concentrations which correlate with the low bulk metal constants of ~3 wt% for Bensour and ~2wt% for Kilabo (see figure 1). The metal compositions fall in the upper end of the LL-chondrite range. The low metal contents and high Co and Ni concentrations in the metal suggest that Bensour and Kilabo are among the most oxidized LL chondrites, which seems consistent with their high olivine-Fa contents of ~31 mol%. This indicates they may come from the same area on the LL chondrite parent body or perhaps from a separate parent body with compositions in the upper end of the LL type range.

The cosmogenic noble gas concentrations in these two meteorites are very different (see tables 1 and 2), indicating that Kilabo has a 2-3 times longer CRE age than Bensour. Kilabo also experienced much higher shielding conditions than Bensour, as shown by its unusually low ^{22}Ne/^{21}Ne ratio of 1.04. The three ages based on ^{3}He, ^{21}Ne and ^{38}Ar show good agreement for Kilabo, but not for Bensour. The low ^{3}He age for Bensour is most likely due to loss of cosmogenic ^{3}He, but the low ^{38}Ar age is not well understood.

The high ^{10}Be and ^{41}Ca concentrations in the metal phase indicate that during the last few million years of exposure, these meteorites were relatively small objects in space. The ^{36}Cl concentrations in the metal are ~10-12% lower than usual, which is probably due to the high Ni content of the metal phase. A similarly low ^{36}Cl concentration was previously found in the metal fraction of the St. Severin LL5 chondrite, which contains ~33 wt% Ni [2]. The low ^{36}Cl results for Bensour and Kilabo correspond to $P(^{36}Cl)_{Ni}/P(^{36}Cl)_{Fe}$ ~0.7.

The radionuclide data indicates that Kilabo had a relatively small pre-atmospheric size and was irradiated under low shielding conditions during the last few Myr of exposure. This apparently contradicts the low ^{22}Ne/^{21}Ne ratio that suggests Kilabo had experienced much higher shielding conditions. This discrepancy implies that Kilabo was irradiated under at least two different shielding conditions, with the constraint that the second stage was long enough (>5 Myr) to reach normal saturation values for ^{10}Be and other short-lived radionuclides.

Conclusion: The cosmic-ray exposure history data does not support the theory that these two LL chondrites were part of a common meteoroid stream. However, we cannot exclude the possibility that both meteorites were ejected from their parent body during the same impact event ~13 Myr ago, or 19 Myr ago, assuming that the ^{21}Ne age is more reliable. In that scenario, Kilabo was irradiated for perhaps 30-40 Myr on the surface of its parent body, while Bensour was shielded by at least several meters of material. Such a speculative scenario would be more consistent with the higher CRE age of Kilabo and its low ^{22}Ne/^{21}Ne ratio. A third possibility suggests that the two meteorites may represent fragments from the same large meteoroid that broke up in space > 10 Myr ago.

References: [1] Cole, K.J. and Sipiera, P.P. *LPS XXXIV* (2003), Abstract #1135. [2] Nishiizumi, K., Kubik, P. W., Elmore, D., Reedy, R. C. and Arnold, J. R., (1989), *Proc.LPS XIX*, 305-312. [3] Jarosewich (1990) Meteoritics 25, 323-337, [4] Welten K.C. (2004), pers. com., [5]

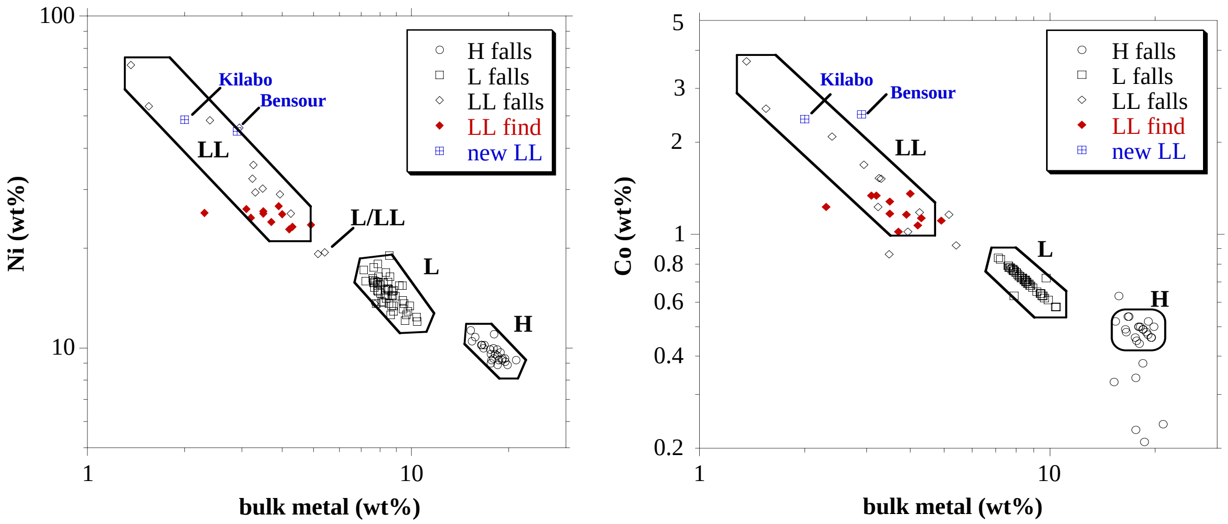

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Figure 1. Measured Ni can Co concentrations (by atomic absorption spectrometry) in the metal fraction of the Bensour and Kilabo LL chondrites, plotted vs. the bulk metal content of 2.0 wt% for Kilabo and 2.9 wt% for Bensour. The results are compared with the metal compositions of 90 H, L and LL chondrite falls (black symbols) analyzed by wet-chemistry [3]. Only falls without Fe_2O_3 are included in the figure. Bulk metal = Fe(m) + Co + Ni, %Ni = Ni/(Fe(m) + Co + Ni), %Co = Co/(Fe(m) + Co + Ni). The red symbols represent the results for 11 members of a large Antarctic LL chondrite shower, QUE 90201 [4], which show relatively constant Ni and Co concentrations of 23-27 wt% Ni and 1.0-1.5% Co.

Table 1. Cosmic-ray exposure ages of Bensour and Kilabo based on measured concentrations of cosmogenic ^{3}He, ^{21}Ne and ^{38}Ar (in 10^{-8} cm^3 STP/g) and production rates from [5]. The low ^{38}Ar age of Bensour is not well understood, whereas the three ages for Kilabo show good agreement, despite the very low $^{22}Ne/^{21}Ne$ ratio, which indicates very high shielding conditions.

Sample	^{3}He	^{4}He	^{20}Ne	^{21}Ne	^{22}Ne	$^{22}Ne/^{21}Ne$	^{36}Ar	^{38}Ar	^{40}Ar	T3	T21	T38	T(avg)
Bensour	21.0	1518	5.64	6.07	6.81	1.123	2.50	0.73	5656	13.1	19.3	7.4	13±6
Kilabo	61.3	1451	14.57	16.02	16.66	1.040	2.25	1.83	5207	37.3	33.0	35.6	35±2

Table 2. Concentrations of major elements (in wt%) and of cosmogenic radionuclides (in dpm/kg) in the stone and metal fraction of the Bensour and Kilabo LL6 chondrites. Based on the high Ni concentrations in the stone fraction, we estimated that the stone fraction contains ~1 wt% of - probably fine-grained - metal.

Sample	Phase	Metal	Mg	Al	Ca	Fe	Co	Ni	^{10}Be	^{26}Al	^{36}Cl	^{41}Ca
Bensour	Stone	~1.0	17.4	1.21	1.31	20.0	-	0.51	19.1±0.4	62.0±1.2	8.3±0.2	7.1±0.5
Kilabo	Stone	~1.0	16.1	1.16	1.36	19.4	-	0.55	23.9±0.5	70.2±1.4	-	7.2±0.4
Bensour	Metal	1.9	0.35	-	-	52	2.5	45	4.85±0.15	4.9±0.4	19.4±0.4	24.4±1.2
Kilabo	Metal	1.0	0.04	-	-	48	2.4	48	5.20±0.15	5.1±0.2	19.6±0.4	24.6±1.0