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18th February 2019

A number of Lead based objects were analysed at the University of Surrey Ion Beam Centre at various times between May 2012 and November 2018. These items included material from an object on loan from the Jordanian Department of Antiquities and other materials of known provenance and some other "books" and "pages" on loan from various places for testing.
The analysis was performed to determine if the object was contemporary or older than 100 years. The test looks for alpha particles emitted from ^{210}Po disintegration (at 5.3 MeV), which is the grand-daughter of the ^{210}Pb as shown in the following figure. The half-life times of the ^{210}Pb and the ^{210}Po (equal to 22.3 years and 138.4 days, respectively) indicate that the yield of alpha particles emitted at 5.3 MeV should be dropped to zero after 200 years (i.e. ~10 half-life time of the 210Pb).

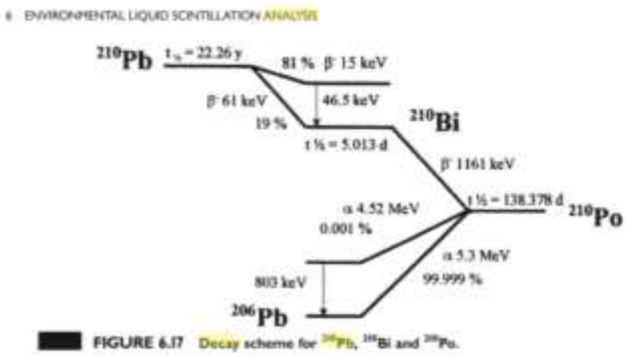

Figure 1

Figure 1: Handbook of Radioactivity Analysis - Second Edition

In each case a small area on the sample was "cleaned" to remove possible environmental contamination from the immediate surface area. A PIPS detector was placed in front of the cleaned area and a second sample (taken from a roll of either "new" 5 year old lead or "older" 45 year old lead shielding) was placed close to a second detector and then left for 3 days to collect any alpha particles emitted by the samples. The samples themselves act as good shielding from any potential background that might come about from any other means.

A summary of the results from the detectors from the accumulation of counts from alpha particles in the expected energy range are shown in the figure on the following page. The results from a number of tests since 2012 are shown to demonstrate that even though there is a potential spread in the results from runs over the years, we can clearly distinguish "modern" lead – from up to 50 years ago from lead older than 200 years and that there is a clear threshold above which we can imply that the lead is “modern” (or contemporary) and below which it is implied that it is “old” – ie more than 100 years.

The lead book, labelled “Dutch book” (light orange) in the figure below, when compared with the control, 5 year old lead, in green, showed substantial activity in the expected range for modern lead. This activity is consistent with the lead being contemporary and inconsistent with it being older than 100 years. Our conclusion, therefore, after this test is that the object is of contemporary origin.

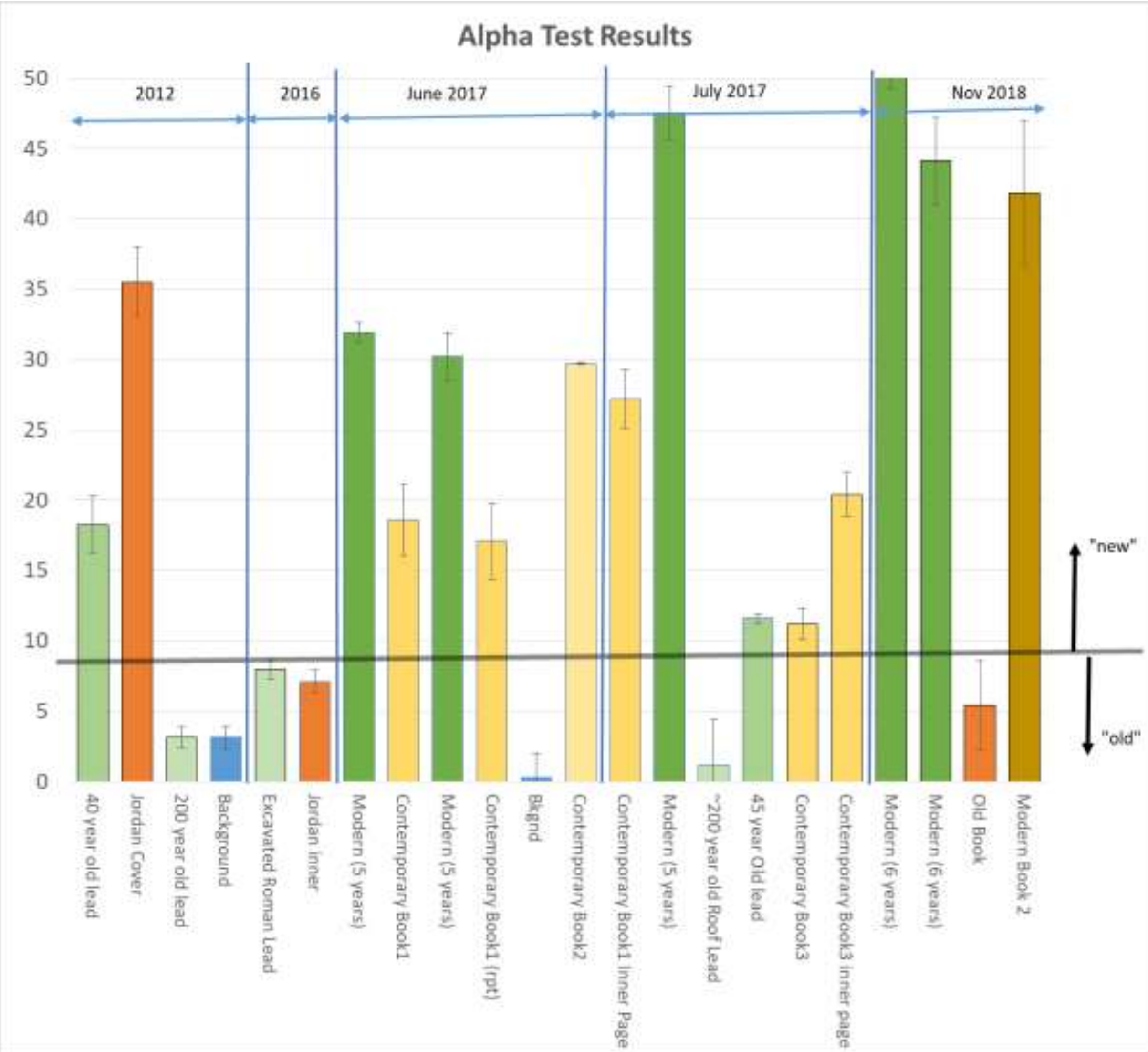

Figure 2

Figure 2: Comparative plot of data obtained over the past 6 years from various lead objects, both “old” and “new”

The first test performed on the Jordan book in 2012 (the second bar in the figure above) showed significant activity, taking into account the half-live of the ^{210}Pb (22.3 years), the alpha particles emitted by the disintegration of the ^{210}Po should no longer be observable after roughly 200 years. This observation was consequently inconsistent with the assumption that the object was a very old piece of lead. However several years later it was noted that the contamination on the outer pages suggested that the object could have been in contact with some sediment for a long period of time. Now, some processes are known to enrich the sediment into ^{210}Pb as illustrates by the following figure.

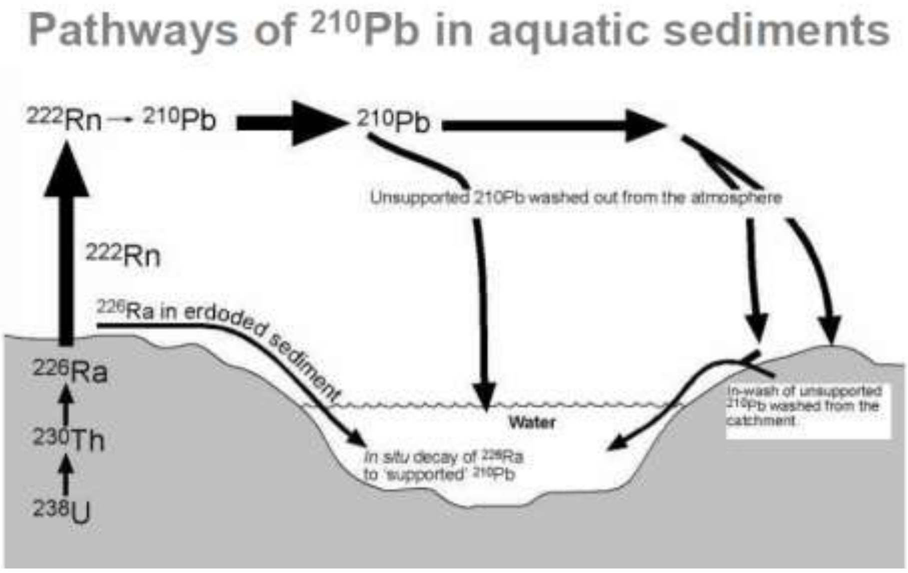

Figure 3: Pathways by which ^{210}Pb reaches aquatic sediments (After Oldfield, F., Appleby, P.G., 1984)

It was this decided that, as the book had been tightly bound, analysis of the inner pages of the object, might avoid the interference of a signal from this possible source of contamination. Measurements were then repeated on an inner page of the book alongside a measurement of a piece of lead taken from a Roman excavation site which had been buried for an extended period of time. These are shown in the 5th and 6th columns on the chart in figure 2. The large reduction in the signal from the inner page confirmed the hypothesis that contamination on the outer pages could be the source of the alpha particles and that, consequently, the object itself was likely to be older than 100-200 years, which is as far back as the test is able to go.

A separate experiment was performed at the National Physical Laboratory in Teddington, UK to look at the ratios of the Lead isotopes. The ratios of the lead isotopes can give information about the age of the ore that was used in the smelting of the lead. Different mines and locations have access to lead ore which is of differing geological age, the age of the rock determines these ratios and hence this can provide some indication of the potential origin of the lead. A data base from Oxford University (OXALID) provides extensive information on places and ores from a large collection of objects. The table below shows the isotope ratios measured from one of the binding rings.

Batch No	Sample Name	Total Pb/(V)	$^{206}Pb/^{204}Pb$	2s %	$^{207}Pb/^{204}Pb$	2s %	$^{208}Pb/^{204}Pb$	2s %	$^{207}Pb/^{206}Pb$	2s %	$^{208}Pb/^{206}Pb$	2s %
P833_41'	Codex_Pb_01	13.0	18.1012	0.006	15.6269	0.007	38.005	0.008	0.86331	0.003	2.0997	0.003
P833_41_Rpt'	Codex_Pb_01	13.4	18.1015	0.005	15.6273	0.006	38.005	0.007	0.86332	0.003	2.0996	0.002

These data were compared with data from the OXALID data base – see figure below – which indicates that the lead is consistent with lead from Roman artefacts originating from European lead mines.

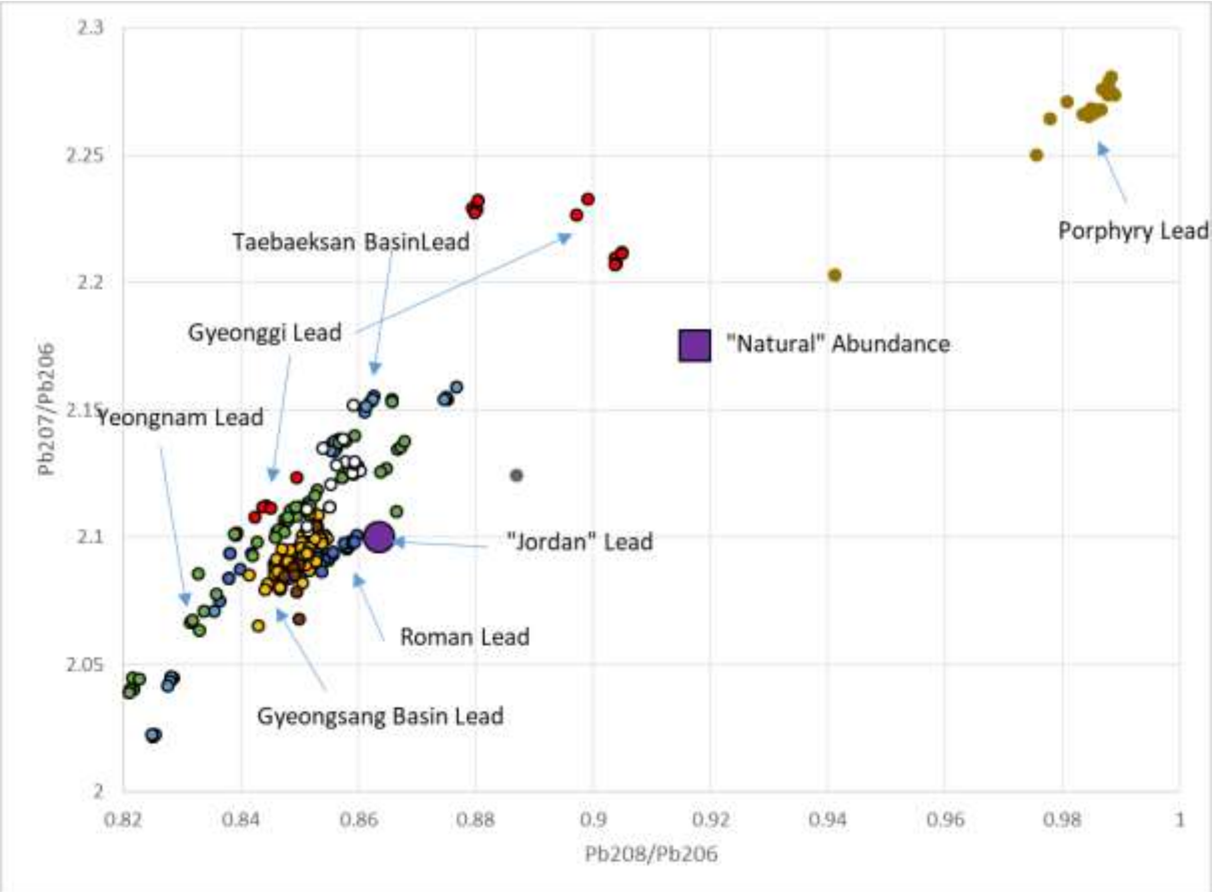

Figure 4: Isotope ratios of "Jordan Codex" lead compared with objects measured and recorded in the OXALID database.

In conclusion it is our opinion that these objects are worthy of further investigation. The evidence points to them conformant with them being ancient, but a definitive test is required to avoid the issues with background contamination of the surfaces of the objects.

Yours faithfully,

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