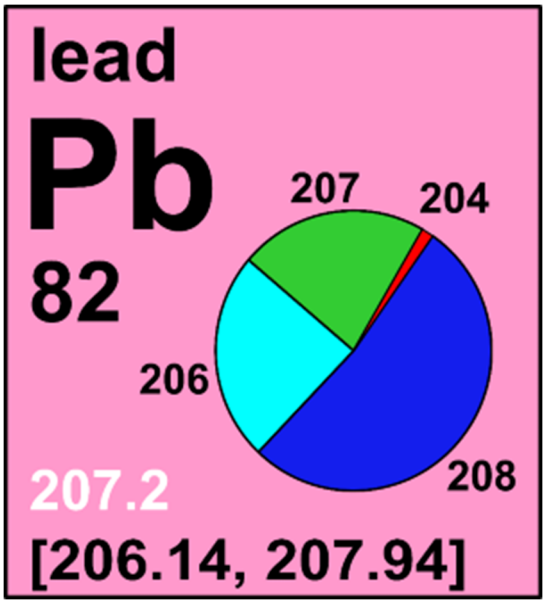
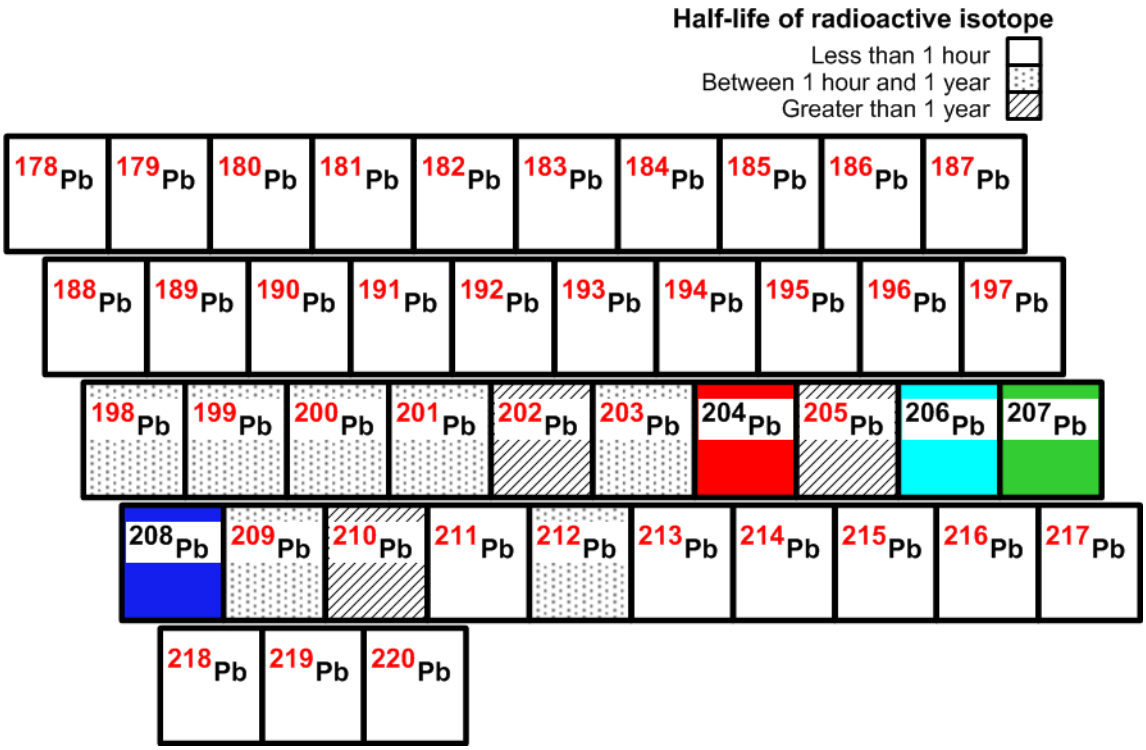
4.82 lead



Stable isotope	Relative atomic mass	Mole fraction
^{204}Pb	203.973 043	[0.0000, 0.0158]
^{206}Pb	205.974 465	[0.0190,0.8673]
^{207}Pb	206.975 897	[0.0035,0.2351]
^{208}Pb	207.976 652	[0.0338,0.9775]



4.82.1 Lead isotopes in Earth/planetary science

The study of lead **isotopic compositions** is used to model the distribution of pollution in water and on land (Figure 4.82.1). For example, in one study of Lake Härsvatten in Sweden, the **isotope-amount ratio** $n(^{206}\text{Pb})/n(^{207}\text{Pb})$ measured at different sediment depths in different areas

throughout the lake showed patterns of accumulation of lead pollution. In some cases, these patterns could be related to sediment distribution patterns. Another study used ^{210}Pb (with a **half-life** of 22.6 years) dating methods to study the vertical accretion of sediments in canals and wetland areas in Louisiana over the last 80–100 years [538, 539].

Three of the **stable isotopes** of lead (^{206}Pb, ^{207}Pb, and ^{208}Pb) are produced by the **radioactive decay** of **isotopes** of uranium and thorium (^{238}U, ^{235}U, and ^{232}Th, respectively) and are largely unaffected by environmental and metallurgical processes. Therefore, by examining various isotope-amount ratios of lead isotopes, it is possible to approximate the age of a material. It is also possible to use this information to trace the origins of an object or material [540-543].

4.82.2 Lead isotopes in forensic science and anthropology

Different geographic regions may have characteristic terrestrial lead isotopic compositions because of variations in the ages and chemical composition of the rocks and minerals in the local environment. Therefore, lead produced at a particular location can have a unique lead isotopic composition and it is possible to trace the history and origins of pollutants by measuring the relative amounts of the four stable isotopes of lead (^{208}Pb, ^{207}Pb, ^{206}Pb, and ^{204}Pb) (Figure 4.82.2) [544, 545]. Using **isotopic abundance** data, the source of this toxic metal can be identified as it moves through air and water and eventually to living systems [544, 546]. Scientists have analyzed lead in air pollution in California and found that it originated from Asia. Airborne particles from China have relatively higher amounts of ^{208}Pb, which distinguishes the lead isotopic signature between airborne particles from Asia and North America. This knowledge could have implications in understanding the mixing of particles in the atmosphere and how pollutants are transported over vast distances [544, 546-548]. Mapping the distribution of lead pollution by studying ^{204}Pb, ^{206}Pb, ^{207}Pb and ^{208}Pb also allows the identification of those human activities that contribute the highest amounts of lead to the environment [544, 546, 549].

The measurement of the isotopic composition of lead in blood can help to determine the source of this toxic **element** in the body [550]. Lead is stored in bones and teeth. If a person moves to a different geographical region, the isotopic composition of the lead in the teeth is maintained, recording their place of origin. Bone can store lead for long periods of time (about 20 years), and some skeletal lead may be older and have a different isotopic composition than other skeletal lead. These differences reflect exposure to lead of different origins. By studying the isotope-amount ratio $n(^{206}\text{Pb})/n(^{204}\text{Pb})$ and $n(^{207}\text{Pb})/n(^{206}\text{Pb})$ in bone and teeth, it is possible to determine someone's place of origin. For example, isotopes of lead were analyzed in the teeth and bones of a human mummy, known as the "Iceman", to help determine his place of origin [551, 552].

^{210}Pb is a relatively short-lived **radioactive isotope** of lead that is constantly produced by the decay of ^{222}Rn in the atmosphere. While living, humans naturally incorporate ^{210}Pb from the environment into bones and tissues. The amount of ^{210}Pb in the body reaches equilibrium such that the ^{210}Pb ingested is in equilibrium with the ^{210}Pb that decays. When a person dies, this incorporation of ^{210}Pb ceases and the relative amount of this isotope in the body decreases. Therefore, measurement of the ^{210}Pb activity in a corpse can help determine time of death [553, 554].

Lead isotope-amount ratios ($n(^{206}\text{Pb})/n(^{204}\text{Pb})$, $n(^{207}\text{Pb})/n(^{204}\text{Pb})$, and $n(^{208}\text{Pb})/n(^{204}\text{Pb})$) along with isotope-amount ratios of silver ($n(^{107}\text{Ag})/n(^{109}\text{Ag})$) and isotope-amount ratios of

copper ($n(^{65}Cu)/n(^{63}Cu)$) have been used to determine the origin of European coins (see section 4.29 on copper) and to investigate the flow of goods in the world market over time [234]. Metals from Peru and Mexico and those from European mining have distinct isotopic signatures that enable the origin of the metal to be determined by examining the isotopic compositions of silver, copper, and lead in the coins. Abundant silver sources mined in Mexico and Peru in the 16th century were used to mint coins, but were not a major influence in the European coin market until the 18th century [234].

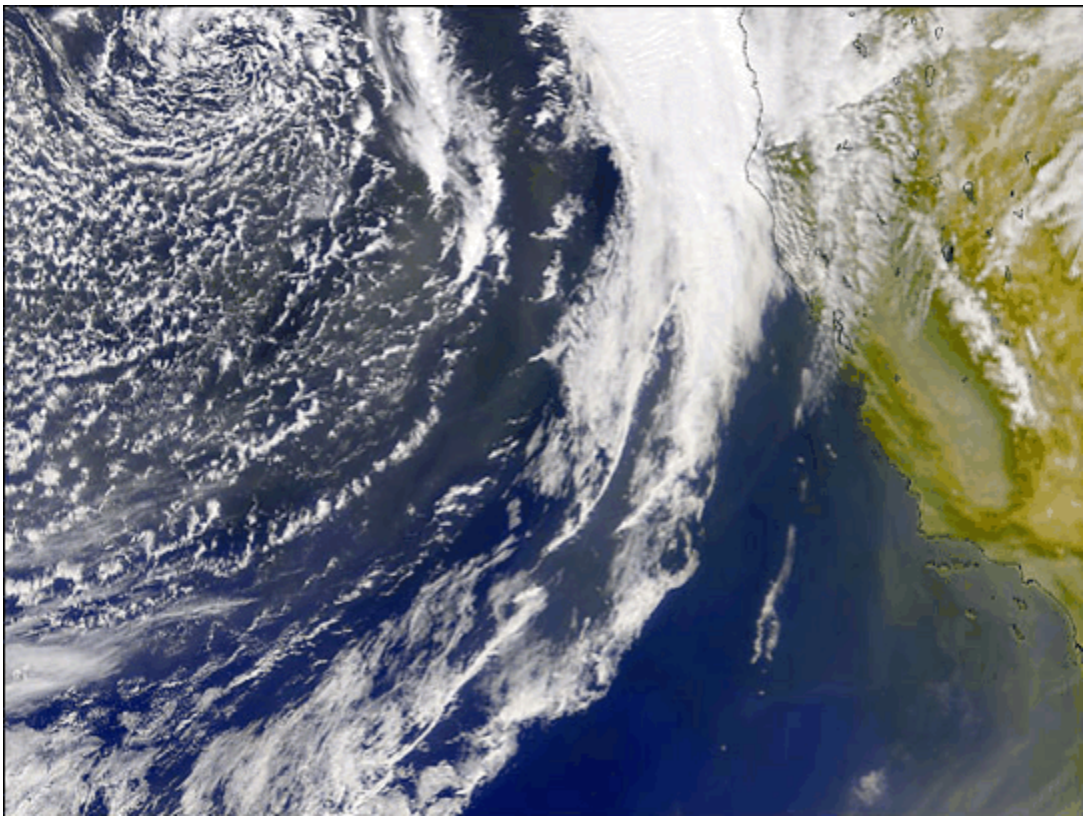


Fig. 4.82.1: Suspended atmospheric dust over California; it is likely that this dust originated in Asia based on lead-isotope studies. (Photo Source: SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE, NASA Earth Observatory, 2001) [548, 555].

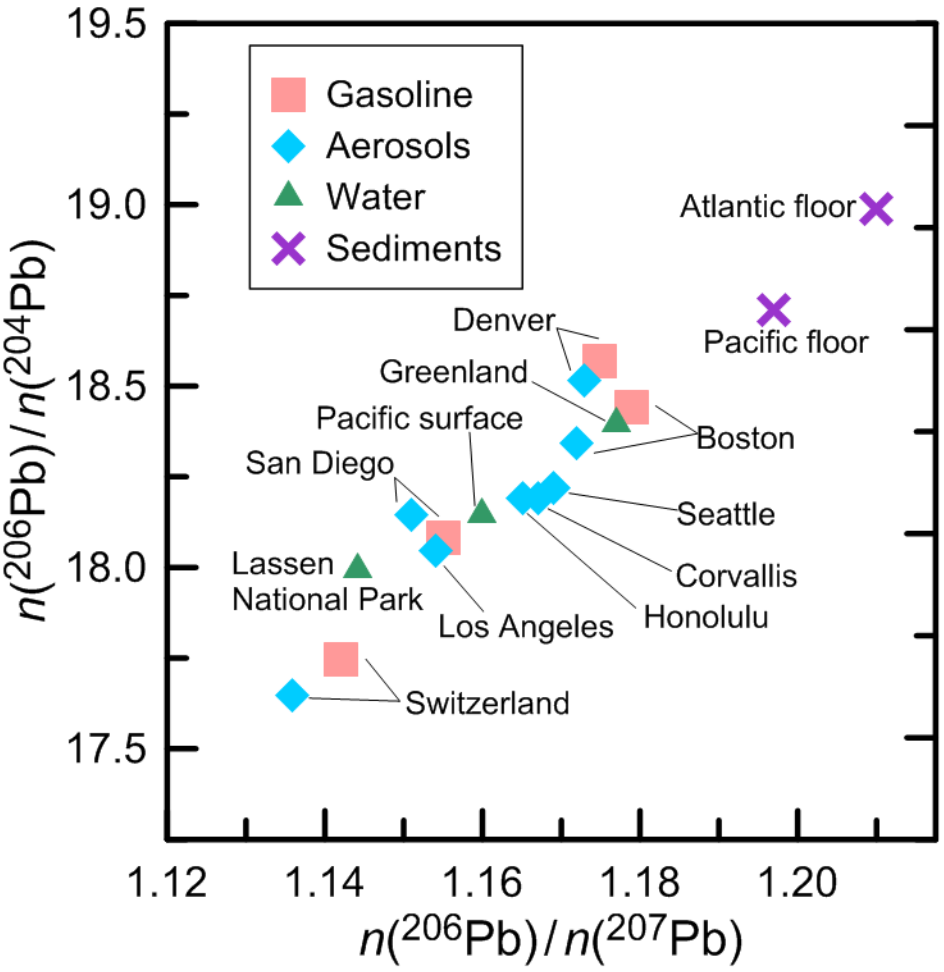


Fig. 4.82.2: Cross plot of $n(^{206}Pb)/n(^{204}Pb)$ and $n(^{206}Pb)/n(^{207}Pb)$ **isotope-amount ratios** of lead in selected materials (modified from [545]).

4.82.3 Lead isotopes in geochronology

The three natural radioactive-decay chains beginning with ^{238}U, ^{235}U, and ^{232}Th each have comparable half-lives that are much longer than the radioactive isotopes that follow until the production of stable isotopes of ^{206}Pb, ^{207}Pb, and ^{208}Pb, respectively. Therefore, one can measure the relative amounts of the **radiogenic** isotopes of lead to determine the length of time that elapsed since uranium and thorium atoms were incorporated into rocks and minerals. Typically, this method is used to date minerals that are tens of millions to billions of years old. The uranium-lead dating method was used to determine some of the first accurate ages of the Earth (~4.55×10^9 years) [551-553].