Once penetrated into the lungs, asbestos induces an in vivo biomineralisation process that leads to the formation of a ferruginous coating embedding the fibres, and that is believed to contribute to their high toxicological outcome. Lung tissue of people subjected to prolonged occupational exposure to asbestos was investigated combining synchrotron radiation phase-contrast and fluorescence tomography. These techniques allowed to reveal the morphology and elemental composition of asbestos bodies (the ensemble of asbestos fibres and their coating) with unprecedented level of detail. The combination of the two techniques also allowed to obtain a more reliable spatially resolved elemental quantification. Elemental quantification confirmed that the coating is highly enriched in Fe (~20% w/w), while the other species are present in trace amounts (0.01 – 0.1% w/w). XANES spectroscopy indicated that Fe is in the 3+ oxidation state, and confirmed that it is present in the form of ferrihydrite, a poorly crystalline Fe oxide that constitutes the mineral core of Fe-storage proteins in the human body (ferritin and hemosiderin). Light elements, such as P, K, and Ca were found to be co-localized in the asbestos bodies, while the distribution of Si suggested an incipient dissolution of the fibres. Comparison between asbestos bodies studied upon removing the biological tissue by chemical digestion, and those embedded in histological sections, allowed revealing that P, K, and Ca are present as soluble species that are removed during the digestion procedure. The observation and quantification of elements heavier than Fe (Zn, Cu, As, and Ba), observed for the first time, indicated that asbestos bodies are efficient scavengers for these species, in agreement with the uptake ability of ferrihydrite. A growth model of the asbestos bodies is proposed based on the observation of the elemental distribution of Fe and other elements.