In this paper, we develop a novel robust optimization approach to source localization using time-difference-of-arrival (TDOA) measurements that are collected under non-line-of-sight (NLOS) conditions. A key feature of our approach is that it does not require knowledge of the distribution or statistics of the NLOS errors, which are often difficult to obtain in practice. Instead, it only assumes that the NLOS errors have bounded supports. Based on this assumption, we formulate the TDOA-based source localization problem as a robust least squares (RLS) problem, in which a location estimate that is robust against the NLOS errors is sought. Since the RLS problem is non-convex, we propose two efficiently implementable convex relaxation-based approximation methods to tackle it. We then conduct a thorough theoretical analysis of the approximation quality and computational complexity of these two methods. In particular, we establish conditions under which they will yield a unique localization of the source. Simulation results on both synthetic and real data show that the performance of our approach under various NLOS settings is very stable and is significantly better than that of several existing non-robust approaches.