Developing reliable, quantitative models of volcanic eruptions is hindered by our inability to observe pre-eruptive conditions directly. The closest we get to direct evidence is testimony imprinted on individual crystals or bubbles in the conduit and preserved by rapid cooling during eruption. For example, small crystal aggregates in products of the 1959 eruption of Kīlauea Iki, Hawaii contain intergrown crystals separated by large, hydrodynamically unfavorable angles. The common occurrence of these aggregates in field samples calls for a flow mechanism that creates this particular crystal misorientation. Here, we link an analytical to a numerical model of volcanic conduit flow at the scale of individual crystals to decipher quantitative attributes of the flow at the time of aggregate formation.