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Short communication

Density of fallen ash after the eruption of Tambora in 1815

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Abstract

A reassessment of the ash density associated with the eruption of the volcano Tambora, Indonesia, in 1815 is presented by examining contemporary reports. This eruption produced the largest known ashfall in historical times. The density of the fallen ash at Makassar, about 380 km north of Tambora, can be safely stated to be 636 kg m^{-3}.
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The classic example of a volcanic eruption that may have temporarily affected the world's climate is the huge explosion of Tambora, Indonesia, in April 1815 (Francis, 1993). Tambora's eruption was also the most productive of fine ashfall in historical times. As such, one would think that Tambora's vital statistics should by now have been consistently estimated and correctly stated, even if the necessary input data have never been particularly well determined. Remarkably, this is not the case. It appears something of an embarrassment that the very paradigm of a volcanic eruption currently has one of its basic parameters still misstated. The purpose here is to point out and to correct the erroneously cited ash density. It is important to do so because ongoing studies of this eruption require some estimate of this specific physical quantity.

Measured thicknesses of ash over the area of fallout from any volcanic eruption can be formally integrated to yield the total ash volume. To convert this bulk volume to a dense rock equivalent, which obviously has greater physical interest, the mass density of the fallen ash is needed. In the case of Tambora, Stothers (1984) simply assumed a range of possible ash densities running from 500 kg m^{-3} (very loose ash) to 1200 kg m^{-3} (ash-flow tuff). Self et al. (1984) adopted for the Tambora ash a density of 650 kg m^{-3} on the basis of measurements of Mount St. Helens ash when it was freshly fallen (Sarna-Wojcicki et al., 1981), on the grounds that the measured Tambora ash depths likewise referred to a period right after the eruption. Sigurdsson and Carey (1989, 1992) used 611 kg m^{-3} based on an August 1816 report in the *Asiatic Journal* of the measured weight of ash that had fallen at the port of Makassar, about 380 km north of Tambora.

This crucial measurement of the ash's weight was reported originally in an official letter written by Captain Eatwell of the British East India Company cruiser *Benares* and sent to Thomas Stamford Raffles, the lieutenant-governor of Java, who was conducting a

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formal investigation of the eruption. The original letter is reproduced in Raffles's final report of 28 September 1815 (Ross, 1826; Raffles, 1835). In Mrs. Raffles's published version of Eatwell's letter, the ash is referred to as follows: "though an impalpable powder or dust when it fell, it was, when compressed, of considerable weight; a pint measure of it weighed twelve ounces and three-quarters." Ross quotes the weight of ash in numerical form as $12^{3/4}$" ounces. However, Eatwell's letter was also published, in a stylistically more elegant version, in the 20 May 1815 issue of the *Java Government Gazette* and again in the August 1816 issue of the *Asiatic Journal*; both of these sources state the weight of ash as "$12^{1/4}$" ounces. Although the 15 June 1815 issue of the *National Register* cites the *Java Government Gazette* as its source, "12 3-4" ounces is given as the weight. Since the version of Eatwell's letter published by Ross and Mrs. Raffles seems to be significantly less edited than the version published in the *Java Government Gazette*, and since both Mrs. Raffles and the *National Register* have taken pains to indicate the weight of ash in an unmistakable manner, it is evident that they are deliberately trying to correct a misprint in the *Gazette*. The correct weight is almost certainly 12.75 ounces. In that case, the ash density must have been 636 kg m^{-3}.

One possible question about this value arises from Eatwell's statement that the ash, when measured, was "compressed". How much was it compressed? The straightforward implication of his report is that the ash had been naturally compressed by its own weight on the ship's deck, from which it was then scooped up and weighed. There is no reason to believe, and indeed it would not make sense, that the ash had been forcefully tamped down in a container before weighing. Nor had it, as freshly fallen ash, been yet compacted by rain, wind, or sedimentation. Although, in analogy with the Mount St. Helens eruption, the ash density would be expected to vary with distance from the source and across the axis of dispersal, Makassar lies downwind of Tambora in the region of greatest ash fall (Stothers, 1984) and so can be regarded as a sort of average locality. Nevertheless, it must be remembered that very proximal ash and very distal ash in the Mount St. Helens case had a density of ~ 1000 and ~ 100 kg m^{-3}, respectively. On the other hand, there are only a handful of eruptions, all modern, for which any value of the initial uncompacted ash density is available at all.

Although the 4% difference between 611 and 636 kg m^{-3} seems rather small in comparison with the present uncertainties of the true range of the ash density as well as of the total bulk volume of the ashfall, the ash density at Makassar is nevertheless an important statistic of the eruption and deserves to be stated correctly. Modern estimates of the bulk volume of Tambora ash are 103–150 km^3 (Verbeek, 1886), 100 km^3 (Petroeschevsky, 1949), 150 km^3 (Stothers, 1984), 100–200 km^3 (Self et al., 1984), 90 km^3 (Sigurdsson and Carey, 1989), and 93 km^3 (Fierstein and Nathenson, 1992). Sapper (1917) did not attempt to derive an original estimate. Owing to the great crudeness of the ashfall isopachs, the more recent estimates of the bulk volume are not necessarily more accurate than the older ones. If further refinement of the bulk volume becomes possible as a result of better knowledge of the contemporary wind patterns, the obvious benefit of having an accurate knowledge of the ash density will be more substantial.

Basic parameters for the prototype of any important natural phenomenon, such as a great weather-modifying volcanic eruption, should be correctly stated, even if the input data are not in fact accurately determined. All too often, a simple numerical error, unrecognized and uncorrected, propagates through the literature. Such has been the case for Tambora. As corrected here, the density of the freshly fallen ash at Makassar was 636 kg m^{-3}.

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