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Location of Silicic Caldera Formation in Arc Settings

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1. Introduction

Large-scale silicic magmatism is frequently observed in the geological record as plutons or ignimbrites, and yet the processes that produce silicic magma chambers are frequently under discussion. Silicic calderas represent the surface expressions of silicic magma chambers, and thus the study of their spatial distribution may give insight into the tectonic and crustal factors that favor the formation of evolved magmas. Of particular interest is the occurrence of silicic calderas within arc settings, because silicic magmatism at margins is commonly thought to stabilize continental crust. The goal of this study is to determine whether silicic calderas consistently occur “behind” the volcanic front, defined by the stratovolcanoes and shield volcanoes closest to the trench. This phenomenon has been observed, for example, in Mexico (Campos-Enriquez *et al.*, 2005), northern Central America (Rose *et al.*, 1999), and the Central Andes (Seibel *et al.*, 2001), but this study is the first to test whether it is universally the case.

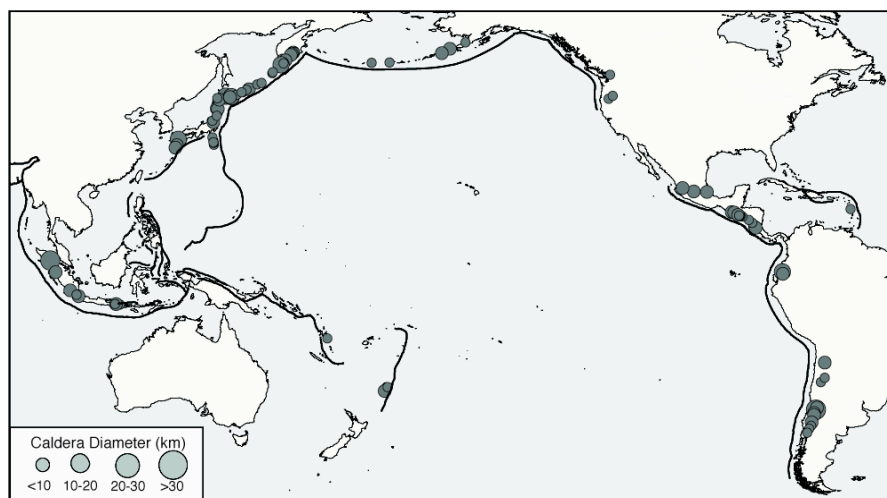


Figure 1: Map of the included silicic calderas in the 17 “simple” subduction zones.

2. Results

We examined 91 calderas in 17 arcs with simple tectonic settings (Figure 1). The calderas used in this study were taken from the compilation by Hughes and Mahood (in revision). All calderas were silicic (greater than 63 wt% SiO₂), larger than 5 km in diameter, and younger than 2 Ma. Arcs were categorized as oceanic (*e.g.* Aleutians), continental (*e.g.* Andes), or transitional-continental (*e.g.* Sumatra). For comparison, we also examined the locations of shield volcanoes and stratovolcanoes, as listed by the Smithsonian Global Volcanism Project (Siebert and Simkin, 2002). Each arc was subdivided into sections 100 km long, and the perpendicular distance from each caldera and volcano in the section was measured to the trench. The distance of the non-caldera volcano closest to the trench was then subtracted from both the caldera and volcano distances. The resulting distances (now with respect to the volcanic front) for caldera and non-caldera volcanoes were then compared.

The most striking result (Figure 2) is the spread of silicic calderas in continental margins over a wide range (from < 10 km to ~90 km) behind the volcanic front. In contrast, all the calderas in oceanic arcs and almost 80% of calderas in arcs with transitional continental crust are located within 20 km of the volcanic front. Occurrence of non-caldera volcanoes in all three arc types decays steadily and rapidly with distance from the front. We conclude then that silicic calderas in continental arcs do form preferentially behind the main volcanic axis.

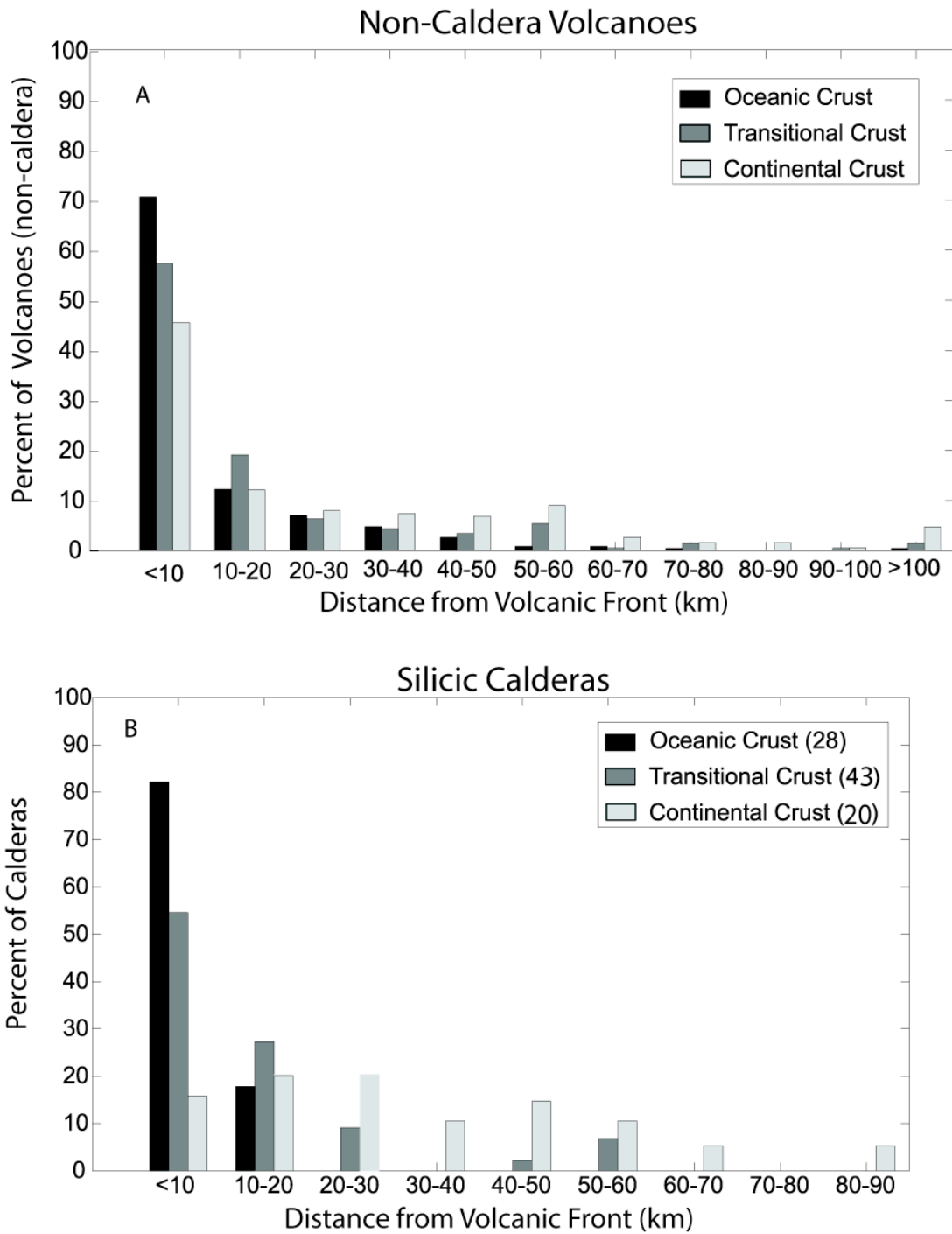


Figure 2: Histograms of the distances of intermediate and mafic volcanoes (non-caldera), and silicic calderas behind the volcanic front. Calderas have been divided into three groups based on the nature of the underlying crust: oceanic, transitional continental (*i.e.* underlain by a continental “chip”). a) Stratovolcanoes and shield volcanoes; b) Silicic calderas.

3. Interpretation and Conclusions

There are several possible interpretations of this result. First, many studies, most recently Lallemand *et al.* (2005), find that slab dip is shallower beneath continental margins than oceanic margins. Volcanic arcs above shallower subduction zones would tend to be wider, and thus observed differences might simply be due to differences in arc width. The result, however, that silicic calderas in continental settings are located over a wide region behind the arc, whereas the number of non-caldera volcanoes in such settings decays rapidly away from the volcanic axis, suggests that the story is more complicated.

A second explanation could be that in oceanic arcs, crust that has evolved by repeated intrusion and partial melting will underlie only the main arc (Tamura and Tatsumi, 2002), where basaltic input is at a maximum. Several studies, (*e.g.* Hildreth and Moorebath, 1988) show that the composition of underlying crust has a profound influence on magmatic composition. Thus silicic calderas in oceanic arcs may only occur in the zone where oceanic crust has evolved by processes of continuous arc magmatism. Finally, during the course of its protracted lifetime, continental crust develops structures such as sutures, fault zones and graben that might channel magma flow and influence whether magma is stored in the upper crust rather than episodically erupted. This accumulated storage time is necessary for the development of large volumes of silicic magma. It is certainly possible that the locations of silicic calderas on continental crust are determined by some combination of these three factors.

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