EVALUATING THE EMPLACEMENT MECHANISMS OF VREDEFORT IMPACT MELT DIKES.

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Introduction: During basin-forming impact events, melted target rocks are preserved in the geological record as sheets, dikes, and irregular bodies at the surface and depth [1]. Impact melt dikes at the deeply eroded, 2.02 Ga Vredefort impact structure, referred to as "granophyre dikes," have previously been shown to have formed later than shock-related *in situ* melt breccia (pseudotachylites) [1,2,3,4]. The dikes contain clasts of shocked target rocks [4,5], and have a Re-Os signature indicative of a meteoritic component [6]. The dikes were formed when molten material from the impact melt sheet migrated along fractures in the basement rocks during the crater modification stage [6,7,8]. The nature and timing of the event(s) that led to melt emplacement remain contentious.

In this work, we use geophysics, geochemistry, and petrography, as well as field relationships, to examine the mechanisms by which granophyre dikes were formed, with implications for the development of large impact basins on the Earth, Moon, and other rocky bodies of the solar system.

Methods: Four granophyre dikes, namely the Kopjeskraal, Daskop, Lesutoskraal, and Holfontein dikes, were investigated by electrical resistivity tomography (ERT), a nondestructive geophysical method described in [8]. Kopjeskraal dike is located at the boundary between the granitic core and the metasedimentary collar of the central uplift of the Vredefort structure (the "core-collar boundary"). The other analyzed dikes represent three of the four exposed granophyre dikes in the granitic core of the structure. Samples from these dikes were analyzed with X-ray fluorescence for bulk chemical composition, according to the methodology described in [9].

Results: *Geophysical data.* The resistivity models obtained from the ERT data for all dikes are shown in Figure 1. The resistivity of the granophyre material is orders of magnitude higher than the host crystalline rocks. The resistivity variation in the host rock is consistent with the expected compositional variation, i.e., granite gneiss to dolerite [8].

At the Kopjeskraal granophyre dike, the highly resistive zone extends past the lowermost depth of the profile (>50 m), so that the terminus of this dike at depth has not been determined (Fig. 1A). The core dikes, however, are distinct from the collar dike (Fig. 1B-D). The high-resistivity zone associated with the Holfontein granophyre dike terminates at ~5 m below the surface (Fig. 1B), and the resistive zones due to the Daskop and Lesutoskraal granophyre dikes terminate ~3 m below the surface (Fig. 1C-D).

Geochemical and petrographic data. The geochemical compositions of the core dikes are generally dacitic, in the compositional range of ~64-72 wt.% SiO_2 and 4-6 wt.% Na_2O+K_2O, in agreement with previous workers [9,10,11,12]. Petrographically, the dikes are composed of intergrowths of feldspar and orthopyroxene that are fine crystalline or spherulitic.

Unlike the core dikes, the Kopjeskraal granophyre dike is composed of two distinct textural and geochemical phases, the Kopjeskraal granophyre A (KGA) and Kopjeskraal granophyre B (KGB). The KGA contains abundant clasts of the granite that may be locally derived. Geochemically and petrographically, the KGA is indistinguishable from the core dikes. The KGB is located approximately 4 m from the contact between the KGA and the host granite and strikes parallel to the strike of the dike. The KGB is finer-grained and darker-colored than the KGA. Rounded clasts of the KGA are included within the KGB. The KGB is intermediate in composition, unlike any previously measured granophyre samples. The KGB has greater CaO, FeO, and MgO than the KGA or core dikes, but less SiO_2 or K_2O.

Discussion: The highly resistive material that corresponds to granophyre dikes does not extend deep into the subsurface. It is unlikely that this result is due to methodological errors, as the same field procedures and data processing were applied to the Kopjeskraal dike and the core dikes, but with no disappearance of material at the Kopjeskraal dike. Additionally, we have numerically modeled the expected results of dikes with varying depths of penetration, and found that the results that we have observed are consistent with the expected result of a dike with a shallow depth extent.

The shallow penetration depth of the core dikes may either be interpreted as the lowermost extent of the fractures that were exploited by impact melt [8], or alternatively, as a representation that the dikes have experienced post-emplacement faulting that offset the dikes either laterally or vertically. The core and collar dikes are preserved differently, perhaps suggesting distinct processes.

There is not an apparent geochemical distinction between the core dikes and the KGA, suggesting that they were derived from the same melt source, and perhaps demonstrating that the initial emplacement conditions of the core and collar were not distinct. The KGB was emplaced after the KGA had solidified, and the KGB has a significantly different geochemical composition. Thus, the granophyre emplacement process must have occurred in a minimum of two discrete phases over an extended timeframe. The intermediate composition of the KGB likely results from the melt source being the lowermost part of a differentiated melt sheet [13]. The intermediate composition has not been found in the core of the structure.

Based on this evidence, we propose that the following series of events occurred:

1) The melt sheet formed at the surface due to the impact event.

2) Shortly after the impact basin formed, fractures developed in the crust and were exploited by molten material from the melt sheet to form the core dikes and KGA.

3) After the KGA was crystallized, the KGB melt intruded, which had a different composition than the first melt pulse. The cause of the change in composition is the differentiation of the melt sheet.

4) Post-impact uplift of the core of the impact basin resulted in distinct preservation of the core and collar dikes.

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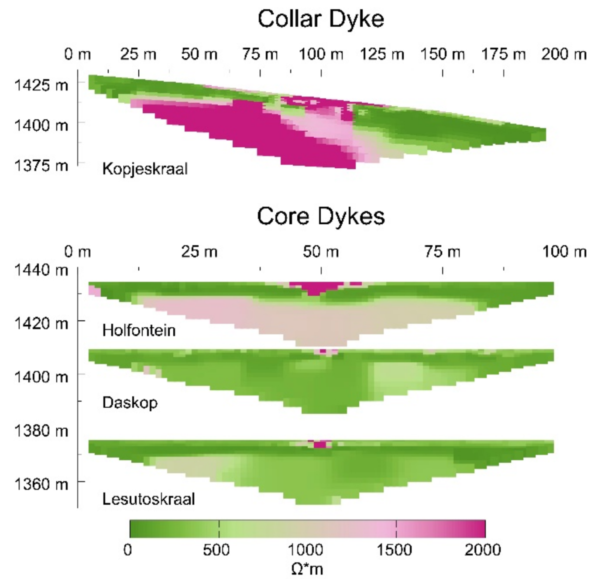

Fig. 1: Resistivity profiles of the granophyre dikes examined in this study, with elevation indicated. Highly resistive material (interpreted as granophyre) is shown in pink, and the host rocks are shown in green.

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