The thermal state of pyroclastic flow deposits of the 4.5 ka Fogo A plinian eruption sequence, São Miguel, Azores, using TRM analysis and charcoal reflectance data, and implications for eruption and flow processes.”

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Geological Problem and Aims

Traditionally plinian eruptions are represented by high buoyant explosive eruption columns rising into the atmosphere, from which widespread pyroclastic fallout deposits are dispersed (Car & Wright, 1987). In many cases increasing mass discharge rates cause the eruption column to collapse gravitationally into the eruption, forming high velocity pyroclastic flows that radiate from the vent area over the landscape. This usually signifies the termination of the eruption. However, some plinian eruption sequences contain evidence that ignimbrites also formed earlier in the eruption, suggesting that some plinian eruption columns are not symmetrical. The causes that lead a steady plinian eruption column to become unsteady and to produce partial column collapse and emplacement of interplinian ignimbrites, are still not well understood. The complex stratigraphy of Fogo A plinian eruption sequence on the oceanic island of São Miguel, Azores, gives us a good opportunity to explore the possible reasons that can produce a complex stratigraphy during some plinian explosive events. The Fogo A eruption sequence consists of an initial very thick and very coarse plinian pumice fallout deposit (Walker and Crowell, 1971), followed by an intermittent emplacement of two interplinian ignimbrites and more fallout deposits, culminating in a final unit of very thick ignimbrite. The ignimbrites vary in terms of their compositional patterns, geometry, thickness and component, and so there is an opportunity to examine if their emplacement temperatures were similar or different. Emplacement temperatures of the three ignimbrites of the Fogo A plinian sequence on São Miguel Azores, have been investigated using thermal remanent magnetisation (TRM) of lithic clasts and reflectance of charcoal fragments embedded within the deposits. The “thermal stratigraphy” obtained with these two methods has been compared with the “compositional stratigraphy” in order to understand the connection between emplacement temperature and component of the deposit and in what way this would be related to the dynamics of the eruption column and the pyroclastic flow system.

Charcoal Reflectance Analysis (Ro=\%)

The preservation of organic material, as charcoal fragments, in pyroclastic deposits is very common. The rank of carbonisation depends on the temperatures of the flow deposit and the position of the fragments within the deposit. Scott and Glasspool (2007) demonstrated that charcoal particles can be used to infer the charring temperature of the wood entombed in ignimbrites. The TRM analysis of 42 lithics collected from the first interplinian ignimbrite (FGA2i1) shows an emplacement temperature of the pyroclastic flow deposits. The total or partial magnetisation of a lithic clast depends by the temperatures reached by the deposit at the time of emplacement. Where the temperature is higher than the Curie point (e.g. 580°C for magmatic, lava flow fragments display only one component of HT is oriented with the Earth magnetic field at the time of emplacement, as lower temperatures lava flow fragments may show two components, in this case the HT would be randomly oriented, while the LT would be co-oriented with the Earth magnetic field of the time of emplacement.

The analysis of the Termal Remanence Magnetization of lithic clasts-embedded within ignimbrite deposits allows to estimate the emplacement temperature of pyroclastic flow deposits. The total or partial magnetisation of a lithic clast depends by the temperatures reached by the deposit at the time of emplacement. Where the temperature is higher than the Curie point (e.g. 580°C for magmatic, lava flow fragments display only one component of HT is oriented with the Earth magnetic field at the time of emplacement, as lower temperatures lava flow fragments may show two components, in this case the HT would be randomly oriented, while the LT would be co-oriented with the Earth magnetic field of the time of emplacement. From TRM analysis of 26 lithics collected from the final ignimbrite (FGA3i1), it is evident the presence of only one population: the HT and the LT, indicating that the emplacement temperature did not exceed the Curie point. The temperature of the deposit could be due to the high concentration of juvenile clast and the presence of high temperature.

Conclusions

The factors that have caused the differences in emplacement temperature for the three ignimbrites are:

- Lower Intraplinian ignimbrite
  - Topography confinement along narrow valleys, high juvenile content and ash content and 40% lithic clast content, relatively low degrees of mixing in cold air in the eruption column and pyroclastic flow.

- Middle Intraplinian ignimbrite
  - Topography confinement along narrow valleys and stratigraphic position between two ignimbrites; very high percentage of pumices and low lithic clast content low level collapse from the eruption column and pyroclastic flow.

- Upper Final Ignimbrite
  - No topography confinement; high content of lithic breccia deposits and low percentage of pumices with respect to the previous deposits; high collapse level from the eruption column and associated ingestion of cold air in both the eruption column and pyroclastic flow.

By combining the data from the TRM analysis and from organic matter reflectances we are able to give a precise estimation of the temperature reached by a particular deposit during its emplacement. This result allows us to reconstruct a detailed thermal stratigraphy of the ignimbrites which constitute the sequence of Fogo A, and validates charcoal reflectance as a valuable tool in paleo-temperatures assessments for Spilltrites.

Field Work Area

The Azores Archipelago (Portugal) is situated in the North Atlantic Ocean and consists of nine islands that formed in the period Pliocene/Pleistocene. The Azores islands are spread along a NW-SE trending zone, 560 km long, in a complex geodynamic setting: it is located near the triple junction of the North American, Eurasian and African plates. São Miguel is the largest of the nine islands and consists of four large intratropical islands and a region of overlapping volcanic rift zones between the volcanoes of São César to the west and Fogo to the east. The São César volcanic is situated in the western side of the island and it is exactly located over the Ribeira de Pena rift axial zone (SN-SW trend), whereas the eastern volcanoes of Fogo, Parnam and Nordeste are aligned along an E-W trend parallel to the EAZP (Meade, 1990).

Paleomagnetic Analysis (TRM)

The preservation of organic material, as charcoal fragments, in pyroclastic deposits is very common. The two population of lithic fragments individuated in the deposit tells us the emplacement temperature of pyroclastic flow deposits. The total or partial magnetisation of a lithic clast depends by the temperature reached by the deposit at the time of emplacement. Where the temperature is higher than the Curie point (e.g. 580°C for magmatic, lava flow fragments display only one component of HT is oriented with the Earth magnetic field at the time of emplacement, as lower temperatures lava flow fragments may show two components, in this case the HT would be randomly oriented, while the LT would be co-oriented with the Earth magnetic field of the time of emplacement.

The TRM analysis of 42 lithics collected from the first interplinian ignimbrite (FGA2i1) shows an emplacement temperature of the pyroclastic flow deposits. The total or partial magnetisation of a lithic clast depends by the temperatures reached by the deposit at the time of emplacement. Where the temperature is higher than the Curie point (e.g. 580°C for magmatic, lava flow fragments display only one component of HT is oriented with the Earth magnetic field at the time of emplacement, as lower temperatures lava flow fragments may show two components, in this case the HT would be randomly oriented, while the LT would be co-oriented with the Earth magnetic field of the time of emplacement. From TRM analysis of 26 lithics collected from the final ignimbrite (FGA3i1), it is evident the presence of only one population: the HT and the LT, indicating that the emplacement temperature did not exceed the Curie point. The temperature of the deposit could be due to the high concentration of juvenile clast and the presence of high temperature.

Paleomagnetic Analysis (TRM)

The TRM analysis of 42 lithics collected from the first interplinian ignimbrite (FGA2i1) shows an emplacement temperature of the deposit between 580-400°C. The two populations of lithic fragments verify that the temperature did not exceed the Curie point. This could be due to the high content of ash and lithic clast content. The three ignimbrites of the Fogo A plinian sequence on São Miguel Azores, have been investigated using thermal remanent magnetisation (TRM) of lithic clasts and reflectance of charcoal fragments embedded within the deposits. The “thermal stratigraphy” obtained with these two methods has been compared with the “compositional stratigraphy” in order to understand the connection between emplacement temperature and component of the deposit and in what way this would be related to the dynamics of the eruption column and the pyroclastic flow system.