Exotic Lava Flows: Carbonatites

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Abstract. The study of exotic lavas on Earth and other planets has been an area of study for quit some time now. On Earth most lavas have high silica content and in order for them to erupt it takes a high eruption temperature. However, the observation of Oldoinyo Lengai in northern Tanzania has led scientists to believe that these are not the only parameters for lavas here on Earth and other planets. One renowned type of lava is Carbonatites, these lavas are well known for their low eruption temperatures (~500-700^oC), and low viscosities (0.005-85Pas, which is lower than the viscosity of water). The first time that these lavas were observed they were not even thought to be lavas because they resembled mudflows and they were not iridescent like other lavas. Further study of these Carbonatites and their volcanic features/deposits it was becoming more apparent that these types of lavas might exist on Venus and other planets besides Earth. The discovery of over 200 channels and valleys from the 1992 Magellan data led scientists to reevaluate the formation of the surface of Venus. Some of these channels were too long to be formed from any basaltic magma, rather that it would take a low eruption temperature, low viscosity lava to form these features. Under optimal conditions a lava erupted at 1500^oC would need a discharge rate of over 3000m^2/s ($3x10^6m^3/s$) with a flow thickness of ~80 meters, to travel 6800 kilometers (longest canali recorded on Venus) before reaching its eutectic temperature. This sort of eruption rate is much greater than for terrestrial flood basalt events to have created. Several lava types were considered to have created these massive canali, but Carbonatites were modeled to accommodate for the Venusian atmosphere so that flows would remain in fluid such as at the Carbonatite volcano Oldoinyo Lengai in Tanzania.

1. Introduction

Carbonatites are igneous rocks composed of more than 50% carbonate minerals (Pinkerton, H., et al, 2000). These rocks have a wide range of compositions, therefore, making classification a challenge. Carbonatites are classified based on what the dominant mineral content is, such as calcite, dolomite and ankanite. Petrologists recognize four different types of Carbonatites based on whole rock analysis: calciocarbonatites (greater than 80% CaO), magnesiocarbonatites (MgO greater than $FeO+Fe_2O_3+MnO$), ferrocarbonatites ($FeO+Fe_2O_3+MnO$ greater than MgO), and natrocarbonatites (alkali-rich- Na, K, Ca). The SiO_2, TiO_2, FE_2O_3 and MnO increase through the sequence (calico→magnesio→ferro-carbonatites). The majority of Carbonatites are intrusive, although there is recent evidence of many explosive and effusive Carbonatites (Pinkerton, H., et al, 2000).

The spatial distribution of Carbonatites on Earth is roughly greater than 330 localities globally. The best-known example, also the only active Carbonatite volcano, is Oldoinyo Lengai in northern Tanzania (Figure 1). This particular volcano rises 3000 meters above the East Rift Valley and is the only locality where natrocarbonatites are found (Dawson, J.B., et al, 1990). Other Carbonatites on Earth are primarily composed of Ca-Mg-Fe carbonates with negligible alkali content (Pinkerton, H., et al, 2000). Other Carbonatites localities are composed of intrusives and pyroclastics, but Carbonatites lavas have also been identified in Uganda and the Kola Peninsula (Pinkerton, H., et al, 2000). Many Carbonatites occur in relatively stable intraplate regions, but some occur near plate margins associated with orogenic activity or plate separation. Other tectonic associations are major lithospheric domes, graben systems such as the East African Rift, faults and Fault intersections and alignments associated with deep-seated fracture zones.

The temporal distribution of Carbonatite production has increased through Earths history. Few Archean Carbonatites are known, so most likely Carbonatites production started by the end of the Archean and continues until the present). Their production is episodic and is apparently linked to major orogenic events.

Figure 1. Summit region on Oldoinyo Lengai (Pinkerton, H., et al, 2000).

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2. Carbonatites

Most lava on Earth has silica contents that range from 30 to 78wt%, and have relatively high eruption temperatures between 800-1170°C (Pinkerton, H., et al, 2000). Carbonatites, however, are non-polymerized ionic liquids having rapid ionic transport so they can have low eruption temperatures ~500-800°C and low viscosities ~0.005Pas-85Pas (having a viscosity lower than water) making Carbonatites the lowest of any magma or lava (Figure 2). These low viscosity and eruption temperatures make it possible for Carbonatites to travel longer distances, which some of these flows are among the longest ever seen.

Carbonatite petrogenesis; there are two competing hypothesis for the generation of Carbonatites. The first being, magmas rise from the mantle as a primary liquid, but there is little evidence to support this hypothesis. Secondly, that Carbonatite magmas separate by immiscibility from CO^2 –rich mafic silicate melts at shallow crustal levels after a prolonged fractionation. Field evidence for this hypothesis is ocelli, diapers, spherules and globules. Isotope and trace element geochemistry and experimental data have been used to test this theory (Kargel, J.L., et al, 1994). There are two alternative models of fractionation, either the magmas are low in alkalis, but fractionate to yield high-alkaline melts (some evidence to support this) or they are high in alkalis, but lose them to yield calcitic/dolomitic magmas. The genesis of Carbonatites is important so there is an improved understanding of important geologic processes such as metamatism, immiscibility, the role of carbon dioxide during volcanic eruptions and the relationship between magma composition and tectonic environment (Pinkerton, H., et al, 2000)

	Carbonatite	Komatiite	Basalt	Rhylolite
Viscosity (Pas)	0.005	0.001-0.1	50	10^7
Density (g/cm3)	1.6(2.2*)	2.8	2.7	2.5
T_{sol} (K)	763(>820*)	1600	1350	850
T_{liq}(K)	1000*	1950	1470	1170

Figure 2. Carbonatite Magma Properties compared to other common terrestrial magmas.

3. Venus

The Venusian canali (Figure 3), and associated volcanic deposits resemble fluvial landforms more than they resemble volcanic features on Earth and Mars. Some canali observed have meandering patterns and features indicative of channel migration that are similar to a meandering river channel and flood plain on Earth. Using Magellan radar wavelength (12.6cm), it shows that the depositional fluvial-type features are among the smoothest terrains on Venus. All of these features suggest that the lava had a water-like rheology and a melting point slightly greater than Venus' surface temperature, thus accounting for the unusual behavior of the lava. Some Carbonatites have these properties; therefore they can flow great distances while retaining a high fluidity(Figure 4), significant mechanical erosive ness, and substantial capacity to transport and deposit sediment (Treiman, A.H., et al, 1983). Data received, reveals that Venusian geochemistry and petrology are indicative of Carbonatite eruptions, which could have mantle and/or crustal origins. Venus' atmosphere (abundant in CO_2, HCL and HF) suggests that the upper crust contains large amounts of calcite, anhydrite and other salts (Gregg, T.K.P., et al, 1993). According to some models, Venusian rocks may contain 4-19% calcite and anhydrite, which adds to the suggestion that Carbonatites are responsible for such features. Carbonatites are also the likely candidates because they support the need to raise the surface temperatures on Venus (660-760K) by only a few tens to a few hundred-degree Kelvin to allow the melting of the surface (Pinkerton, H., et al, 2000). Once erupted, these Carbonatites would remain turbulent for great distances, which would account for the extremely long canali features seen on Venus. It has also been suggested that a molten salt (Carbonatite) "aquifer" may exist beneath a few hundred meters to several kilometers of solidified salt-rich "permafrost" (Kargel, J.S., et al, 1993).

In Conclusion, the research of Carbonatites on Earth and the data and sample that have been collected from Venus conclude that there is evidence of Carbonatite eruptions on the surface of Venus. A number of lava types have also been considered to have formed the Venusian canali and other features on Venus, including komatiite and sulphur flows. Natrocarbonatite lavas were considered to cool at a sufficiently slower rate to allow them to remain fluid for longer distances; therefore Carbonatites would be the primary origin of the canali on Venus.

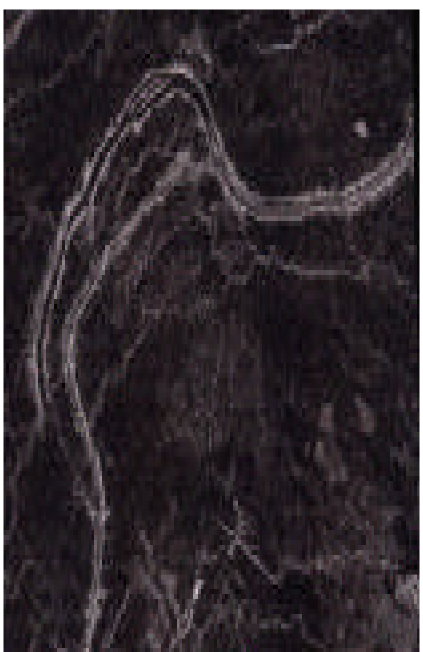

Figure 3. Magellan Image F MIDR 45N019
Channels with meandering features on Venus.

Acknowledgments. This paper was put together to further our understanding of exotic lava flows such as Carbonatites seen on other planets.

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