Figure 1: A typical strombolian eruption occurring at Stromboli. Photo taken by Chouet (1969).

Source mechanisms of tilt at Stromboli Volcano

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Introduction

Stromboli, an Aeolian island located north of Sicily, is a highly active volcano which exhibits a varying array of explosive and effusive activity (GVP, 2011). The explosive activity at Stromboli mainly consists of regular Strombolian eruptions which generally range in frequency from ~10 to 60 minutes (Parfitt, 2004). Strombolian eruptions are the result of gas slug (bubble) rise (Vergniolle and Mangan, 2000). As gas exsolves at depth within the conduit it begins to rise, as the gas rises it begins to coalesce forming a gas slug which continues to move up the conduit (Lane et al. 2010). A gas slug and the forces operating around it are shown in Figure 2. These slugs then reach the surface and burst, forming varying magnitudes of events at the surface, as seen in Figure 1.

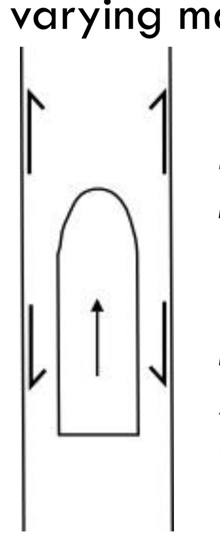

Figure 2: A diagram of a gas slug rising through a cylindrical conduit. The liquid (magma) at the sides of the gas slug falls and creates negative shear on the conduit walls. Above the slug the liquid rises causing positive shear.

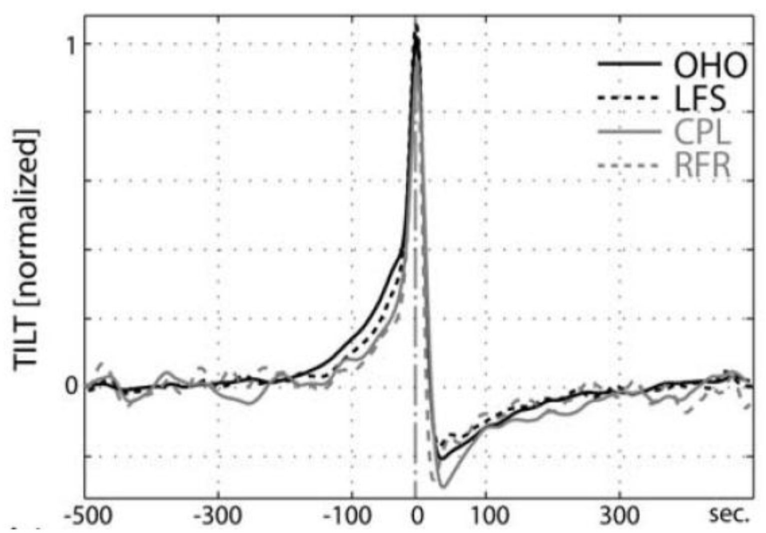

Figure 3: The tilt seen at Stromboli, taken from Genco and Ripepe (2010).

Prior to an eruption at Stromboli (an individual burst), a tilt signal is recorded by tiltmeters at the surface. This signal has been analysed and summarised by Genco and Ripepe (2010), the signal is shown in Figure 3.

The purpose of this research is to determine what mechanism causes the tilt seen at Stromboli, whether it is the magmastatic pressure force of the magma rising in the conduit or whether it is the effect of shear forces on the conduit wall associated with the rise of the slug. This research is important as it will add to our knowledge on mechanisms which occur within the conduit.

Methodology

A three pronged approach is being used, combining field, simulated and experimental data. It is hoped that a mechanism for tilt at Stromboli will be determined. The field data is seen in Genco and Ripepe (2010) and has been produced from tilt signals recorded at Stromboli.

The experimental data will look at the pressure across the conduit as the slug rises and bursts at the surface. A glass tube will be kept at a constant pressure and a varying viscosity of fluid will be used to look at the effect of this on pressure forces. The use of a viscous cap on the surface of the fluid will also be applied, this should simulate the cooling of the magma at the surface between slug bursts.

Using Flow 3D software a number of simulations will be undertaken with a variety of scenarios completed at conduit scale using SI units. The boundary simulations involve a closed conduit (solid top) and an open conduit (open top), whilst the other simulations involve a cap of varying viscosity, again this is intended to simulate cooling of the surface of the magma.

Results and Analysis

Currently two Flow 3D simulations have been completed and analysed; the open and closed conduit scenarios. Three sets of data have been obtained; slug positions, shear forces, and forces acting on the conduit. Figure 4 shows a combination of slug positions, liquid surface and a visualisation of the shear forces acting on the conduit.

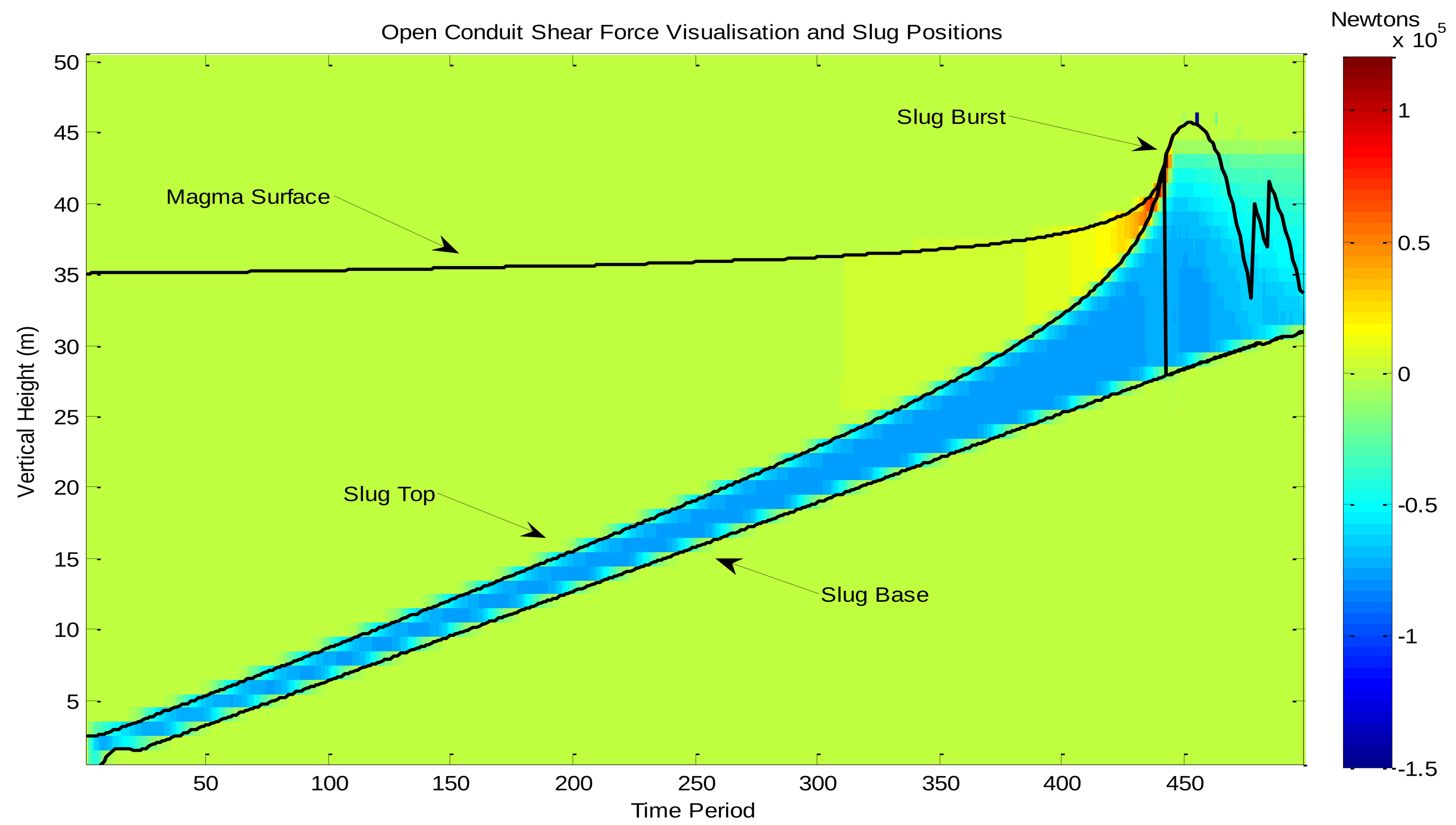

Figure 4: A combination of shear force visualisation, positions of the slug top and slug base and the position of the magma surface for the open conduit scenario.

Figure 4 reveals that along the sides of the slug the shear forces acting on the conduit wall are negative. Closer to the point of slug burst a period of positive shear acting above the slug occurs. As the slug reaches the surface it expands in height, this expansion consequently causes the magma surface to rise with it. As the slug reaches the surface and bursts the magma level drops significantly.

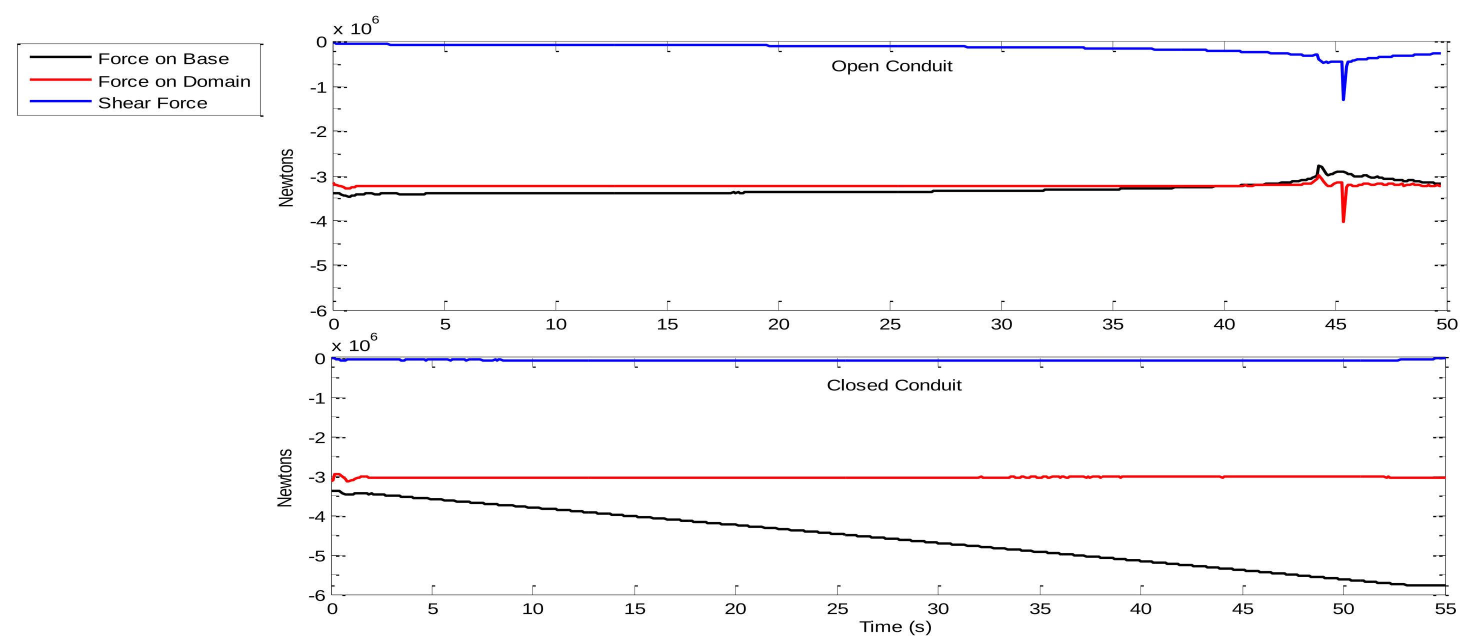

Figure 5: Three forces are plotted for both the open conduit and closed conduit scenarios; force on the base, force on the domain and the overall shear forces acting on the conduit.

Figure 5 shows that, during the open conduit scenario, at the point of burst the shear force and force on the domain decrease and then rise sharply, whilst the force on the base increases slightly. The situation with the closed conduit is different because the slug does not burst at the surface. The only change in force is seen on the base of the conduit which decreases up to the point of burst.

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Discussion and Conclusion

At Stromboli the positive tilt signal starts to increase ~100 seconds prior to the slug reaching the surface (Genco and Ripepe, 2010). The current data gathered from my research does not give enough information to determine a definitive mechanism for tilt. The open conduit simulation provides the most information; it tells us that as the slug rises, shear force increases close to the surface and simultaneously the magma level rises. Therefore, when a positive tilt is recorded, magmastatic pressure and shear forces are acting on the conduit. When the slug bursts a large drop in the magma surface level is recorded, this is when a negative tilt is recorded at Stromboli.

However, the open conduit simulation does not represent the actual conditions which are present at Stromboli. In reality, the surface of the magma will cool between slug bursts, creating a more viscous layer. This alters the shear and pressure forces operating within the conduit. These forces will be investigated further in laboratory experiments and computer simulations. The processes which cause the tilt at Stromboli are shown in Figure 6. Further research will help identify and quantify these processes to determine whether shear forces or magmastatic pressure are more prominent in producing tilt. Shear forces are seen as a plausible mechanism for tilt at Soufrière Hills Volcano, Montserrat (Green et al. 2006).

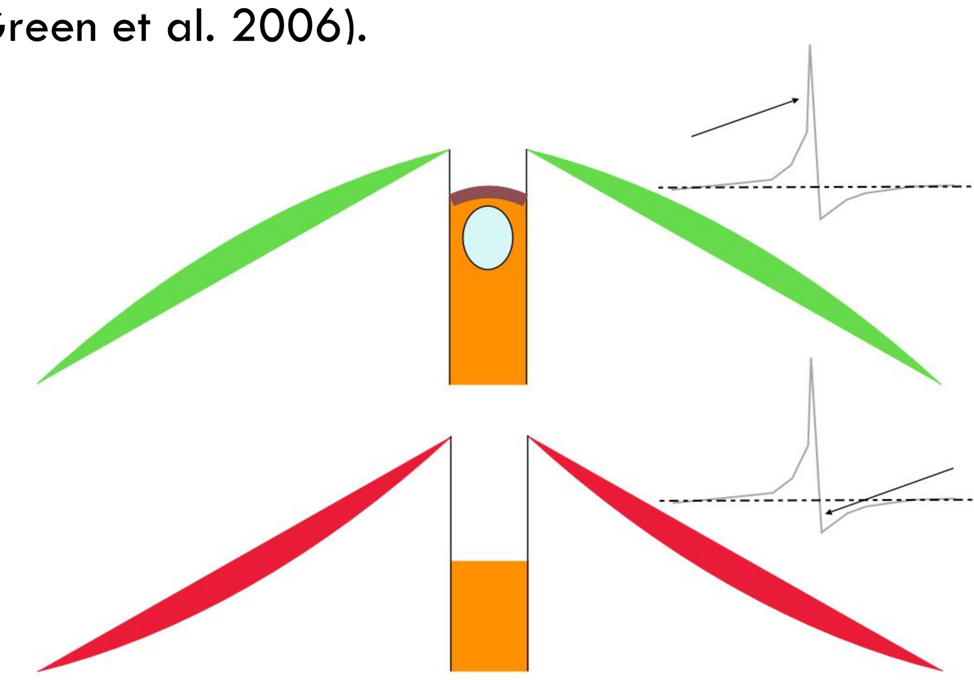

Figure 6: Diagram showing the proposed mechanism for tilt. Inset is the tilt signal for Stromboli (from Genco and Ripepe, 2010) and the position on the tilt signal which the diagram represents. The diagram is not to scale, the tilt of the edifice is exaggerated.

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