The 1991 - 1993 eruption of Mt. Etna: Timescales and nature of magma recharge and mixing

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We have quantified the timescales of magma mixing and residence before eruption by modelling compositional gradients of multiple elements (Fe, Mg, Mn, Ca) in several olivine crystals from the different lava flows that erupted during December 1991, January 1992 and March 1992 at Mt. Etna. Three different olivine populations were identified based on core crystal compositions (Fo70, Fo78, Fo80-82) and these are interpreted as open system involving mixing between three different components (magmas or crystal sources). The difference in core compositions contrasts with the common composition of most rims at Fo70-72 indicating that all crystals share their late magmatic histories. The zoning patterns of these olivine types are: (i) a dominant population of reversely zoned or unzoned crystals with cores at Fo70 and rims at Fo72-74, (ii) a less abundant, normally zoned crystal population with cores at Fo80-82 and rims Fo72-74 (occasionally Fo78), (iii) a subordinate population with crystal cores at Fo75-78, an intermediate zone of Fo80, and rims at Fo74. These types of zoning indicate two distinct mixing events. An early episode between the two high Fo magmas (e.g., cores at Fo78 and Fo80-82) followed by the remixing of this with a more differentiated magma with Fo70 crystals. The results of modelling the chemical gradients indicate that the early mixing event occurred about 100 - 200 days prior to eruption. Crystals showing evidence of this older mixing event are mainly represented in the December 1991 rocks and their proportions decrease in the latter eruptions. In contrast, the times since the last mixing episode with the more differentiated magma are present in all studied rocks, and are in general shorter. They increase from a few days or weeks for the December 1991 products to a few months for the March 1992 deposits. This sequence of events and time scales may be explained by arrival of an already mixed magma to a shallower reservoir containing the differentiated magma. The observation that the times since this last mixing event increase with eruption sequence indicates ageing of the crystals in this shallow reservoir which was simply being emptied after an initial recharge of mixed, mafic melt that may have triggered the eruption. This single recharge was apparently sufficient to sustain the eruptive activity during the December 1991 to March 1992 eruptions.

Aerobic and anaerobic microbial ecosystem recorded in the Steep Rock Group, Ontario, Canada

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The Steep Rock Group is mainly composed of ca. 3.0 Ga submarine volcanic and sedimentary rocks. Thick carbonate unite, containing stromatolite, is the well-known characteristic of this group. The stromatolite is overlain by other carbonate, black cherts, black shales and carbonaceous massive sulfides, although most outcrops were mined out.

Carbon isotope compositions of kerogen in the examined samples range from -37 to -23 ‰. The heaviest carbon isotope composition is found in the stromatolite sample. SEM observation indicate that kerogen in stromatolite samples often contain micro-crystals of Mn and Fe oxides. Such Mn and Fe oxides were most likely formed during diagenesis using dissolved oxygen in shallow water and have distinct characteristics compared to the secondary Mn and Fe oxides formed by Phanerozoic weathering. These mineral and isotopic characteristics suggest the aerobic microbial activities during the formation of stromatolite. The lightest carbon isotope composition was found in black shale samples, suggesting the activity of methanotrophs during the black shale sedimentation.

Micro-scale sulfur isotope compositions of pyrite were also determined by the laser microprobe system. Sulfur isotope compositions of pyrite in black shales and massive sulfides rang from -8 to -5 ‰. Such isotope compositions, small range and pyrite texture suggest that microbial sulfate reduction in stratified ocean water followed by syngenetic pyrite precipitation from deep euxinic ocean water. Those all data indicate that variety of microbial ecosystem, corresponded to the paleo-water depth, existed in the 3.0 Ga Steep Rock oceans.