MAGMA SYSTEMS IN THE GALAPAGOS ISLANDS: INSIGHTS ON THE TRANSITION BETWEEN CRYSTAL RICH AND CRYSTAL POOR CONDITIONS

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ABSTRACT

Ocean island, mid-ocean ridges and arc magmatic systems share a remarkable dynamic and architectural similarity in that they display a temporal evolution where the dynamics and compositional evolution requires progressive or repeated transitions between crystal poor and crystal rich- "mushy" conditions.

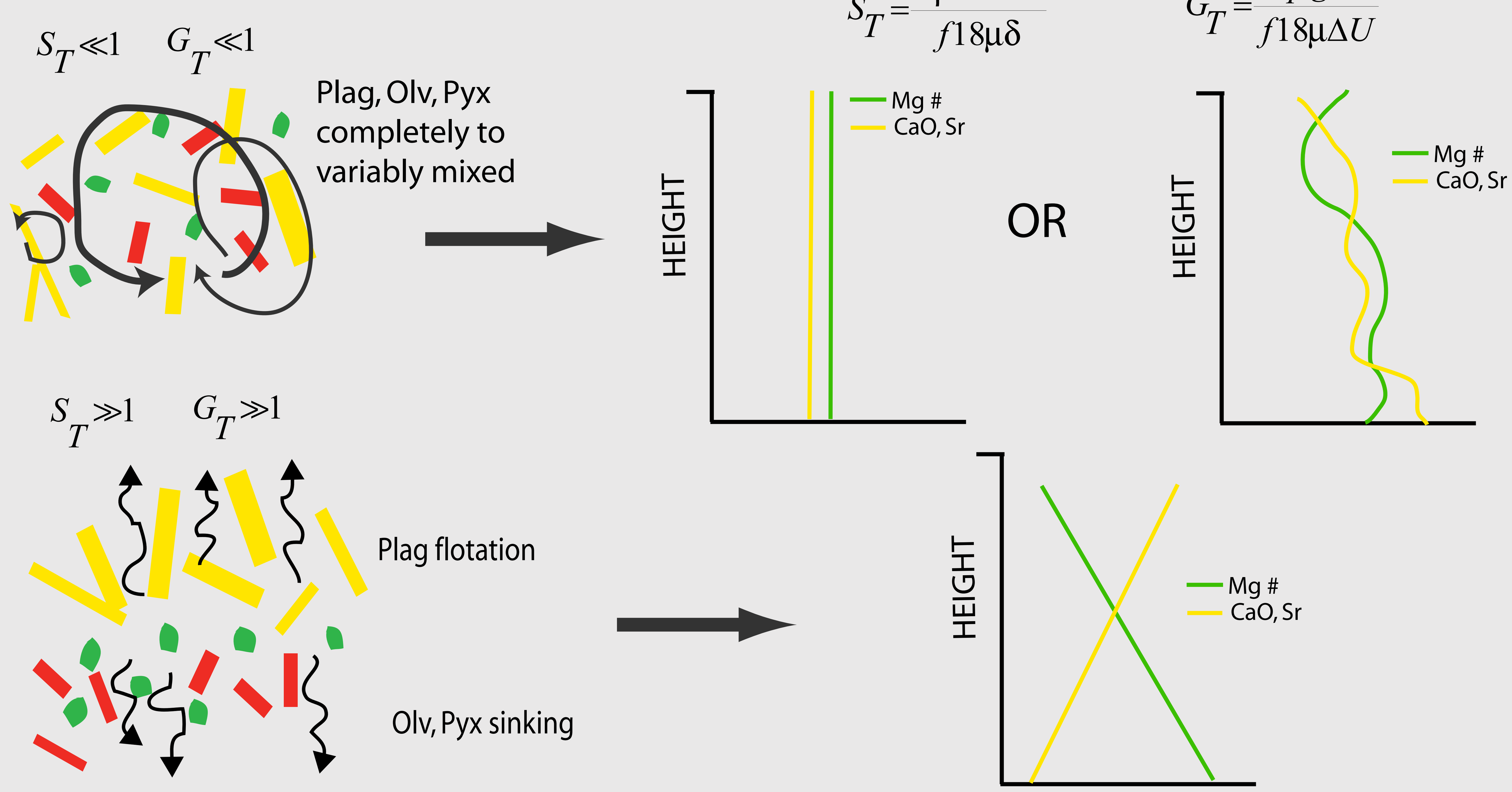
This is manifested in the Galapagos where three general types of magmatism are recognized: diverse, monotonic, and dying. Each of these types reflects the waxing and waning thermal maturity and hence the time-integrated mass flux in this order: diverse-monotonic-diverse-dying.

To first order, the compositional variability of each of these distinct stages reflects the primary control that moderate to high crystal fraction exerts on the dynamics- primarily by the relative buoyancy of crystal phases and the onset of contiguity. Despite having significant crystal fractions, the magma systems of both monotonic and diverse are dominated by fluid-like behavior, while the smaller volume, more evolved dying systems reflect processes where the solid phases are relatively immobile. This suggests that Eulerian theories like 'compaction' are not significant through-out the most volumetrically important magmatism, and that a rich variety of unrecognized and poorly understood Lagrangian processes may be more significant for most of the volcanic history.

DIVERSE: SMALL VOLUMES TO PROGRESSIVELY ORGANIZED CRYSTAL SLURRY

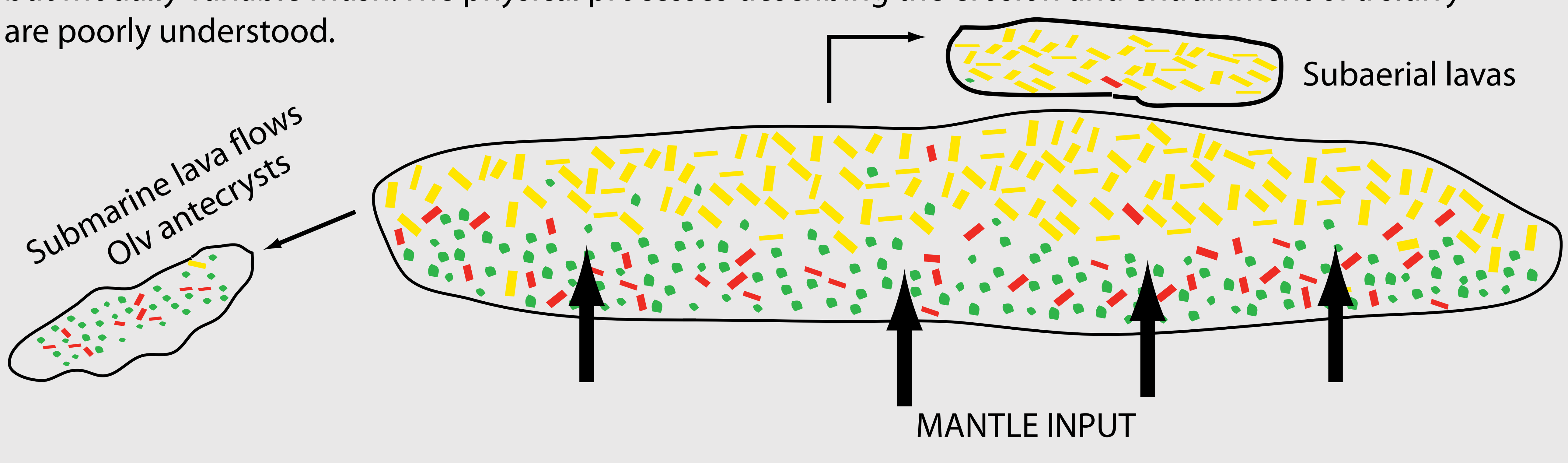
Diverse magmas form by the progressive unmixing of the crystal cargo by floating of plag and settling of olivine and pyroxene. In the fluid-dominated early portion, complexity arises by the interaction of non-steady inertial coupling of particles and fluid, and the steady acceleration of gravity. These two proceses are characterized by the Stokes number and the Gravitational Sedimentation number:

$$S_T = \frac{\Delta\rho\, d^2 \Delta U}{f 18 \mu \delta} \qquad G_T = \frac{\rho_p\, g d^2}{f 18 \mu \Delta U}$$



MONOTONIC: FROM PLEXUS TO NEXUS

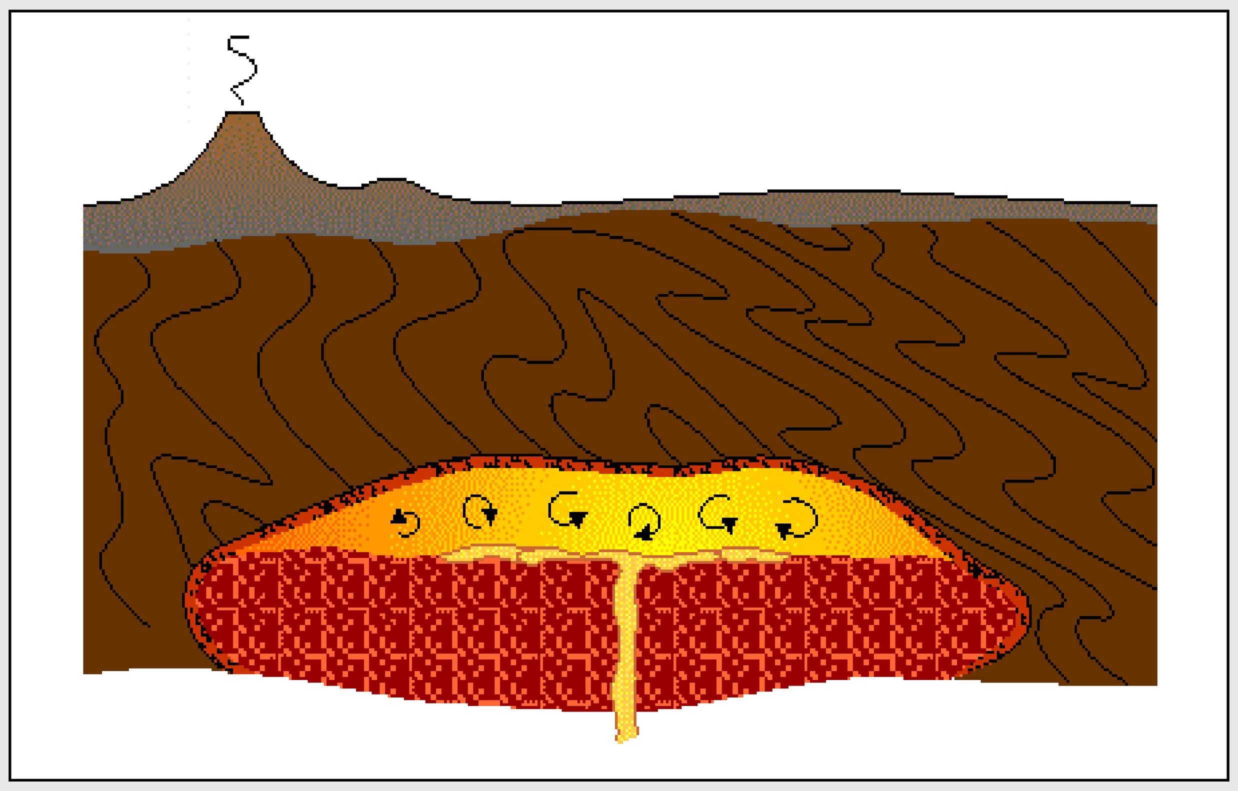
High-volume, thermally buffered monotonic systems reflect the physical integration and partial homogenization of the diverse stage. The physical state of the system is one of high crystal fraction, but without pervasive contiguity. Hence new inputs will interact with a large volume of thermally buffered but modally variable mush. The physical processes describing the erosion and entrainment of a slurry are poorly understood.



DYING- HIGHLY EVOLVED MELTS

In the dying stage, the crystal mush reaches mechanical contiguity. Compaction, compositional convection, gas sparging and melt migration from the physical 'tearing' of the roof-zone can act as collection mechanisms.

That highly evolved melts are not a volumetrically significant phase in the Galapagos or ocean island systems presents an enigma: if the active phase is dominated by large crystal mushes, compaction and compositional convection should be efficient and highly evolved melts more common. It is unlikely they result simply from 'physical tearing' of the mush as mafic recharge is observed with the rhyolites at Alcedo.



Based on observations from Alcedo we will discuss one model for evolved melt extration and distribution from subjacent, but immobile, crystal mush. However the general applicibility of this model for highly evolved melts in the ocean island setting is unclear.

SUMMARY

At the largest scales, the controls on the magmatic styles in the Galapagos are:

1) Diverse: Varible schedule of inputs produces magmas whose diversity is goverend by fluid dynamics of multiphase mixing and rapid, polybaric crystallization.

2) Monotonic: Asembly into systems whose size is significantly greater than inputs, large magma mush provides thermal buffering and complex crystal cargo under crystal-rich, but mobile, conditions.

3) Dying: These systems raise the interesting question- are evolved melts common but generally uneruptable? Or is recharge fundamental to their segregation and eruption?