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Effect of permeable flow on cyclic layering in solidifying magma bodies: Insights from an analog experiment of diffusion-precipitation systems

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Characteristic structures such as rhythmic layering, cress cumulate, cross bedding, perpendicular feldspar rock etc, are commonly observed in layered intrusion or shallow magmatic intrusions. These structures result from complex processes including thermal and compositional diffusions, crystallization, crystal settling, convection and interaction among three phases (crystals, bubble, melt). In order to understand how the differentiation proceeds in solidifying magma bodies from each characteristic structure together with chemical signatures, it is necessary to evaluate the relative importance among these elemental processes on structures. As an attempt to evaluate the effect of advection on a diffusion-related structure, we carried out an analog experiment of Liesegang system using lead-iodide (PbI2) crystallization in agar media which have been normally used to prohibit convection. In the ordinary Liesegang band formation experiments including only diffusion and crystallization kinetics without any advection and convection, the precipitation bands develop with regular spacing following a geometric progression due to two-component diffusion and reaction with supersaturation. This type of banding structure has been advocated as the same type of cyclic layering or vesicle layering (a sort of rhythmic layering) in dykes or sills. In order to see the effect of one-directional advection on Liesegang band, we apply the electric field (5 V to 25 V for a distance 15 cm) along the concentration gradient in agar media, thereby counteracting flows of lead anion Pb2+ and iodide ion I- are driven at constant velocities. The flows of anions and ions are equivalent to the permeable flows in porous media of crystal mush. The resultant precipitation structures exhibit very curious banding structure in which band spacings do not change with distance, are nearly constant and quite narrow, depending on the voltage, unlike those in ordinary Liesegang bands in which band spacings increase with distance following geometric progression. Further interestingly each band consists of a lot of very tiny irregular-shaped crystal aggregates. From experimental results and scaling arguments, with regard to the effect of one directional permeable flow on band spacing of cyclic layering, we propose a hypothesis of constant Peclet number that Peclet number (ratio of flow velocity to diffusive velocity) is nearly unity. By applying the hypothesis to natural examples, we can estimate a value of permeable flow velocity of interstitial melts in differentiating magma bodies from values of a band spacing and diffusivity data.