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Mechanics of Mafic Dyke Swarms and Breakup of Supercontinent

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Dyke swarms can be divided into three types: parallel dyke swarms, radiating dyke swarms and fan-shape dyke swarm, for which the mechanisms of formation are different (Fig. 1). Parallel dyke swarms form in response to a regional stress field, for example, the NNW-trending mafic dyke swarms widespread developed in the the North China Craton (Hou et al., 2006a,b; Peng et al., 2007, 2011). The radiating dyke swarms are developed due to stress concentrations around a volcanic edifice, as in the case of the radiating dyke swarm at Spanish Peak, USA. The fan-shape dyke swarms conclude two parts: radiating dyke swarm and parallel dyke swarm, for example, Mackenzie dyke swarm (Halls, 1987; Ernst et al., 1995). In the factors controlling the emplacement of dyke swarm, fractures that formed prior to magmatism may play a role in dictating dyke swarm geometry. In most cases pre-existing fractures are induced by tectonic stresses and not by magma injection though magma injection can increase fracture size by fracture propagation at the dyke tip.

The regional stress field is very important factor to control the distribution of parallel dyke swarm. Usually the parallel dyke swarms are controlled by the regional extension stress field which tectonic forces come from the boundaries of the plate. The "pre-existing hole" model (Fig. 2A) for the formation of radiating dyke swarms can explain the mechanism of small-scale radiating dyke swarms related to the volcanic edifice, but not provide an explanation for the size of giant radiating dyke swarms related to mantle plume (Park, 1995). In the case of the 2100 km long Mackenzie dyke swarm of the Canadian Shield, radiating dykes occur around a focal source but with distance, dyke orientations swing from N-S to NW-SE and the dyke swarm adopts the geometry of a parallel dyke swarm.

The mechanics of the giant radiating dyke swarms, i.e., Mackenzie dyke swarm, is very complex. A "Plug" model based on the results of two dimension finite element modeling is proposed to explain the mechanism of formation of the Mackenzie dyke swarm (Hou et al., 2010) (Fig. 2B). Hou's "Plug" model can explain the development of radiating dykes concentrated around the focal area and parallel dykes far from the magma source during opening of the Grenville Ocean. The model is a "plug-like" model that invokes local stress concentrations

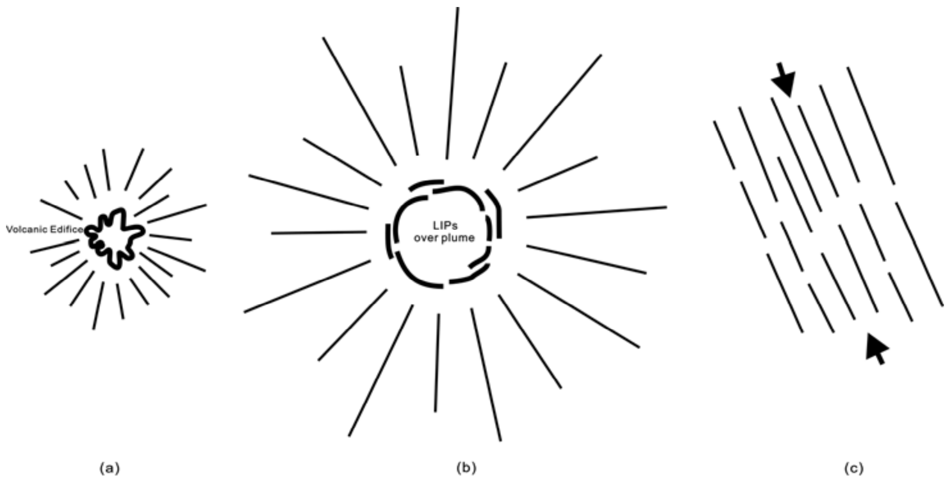

Fig. 1. Three types of dyke swarms. Arrow indicates the regional maximum principle compressive stress.

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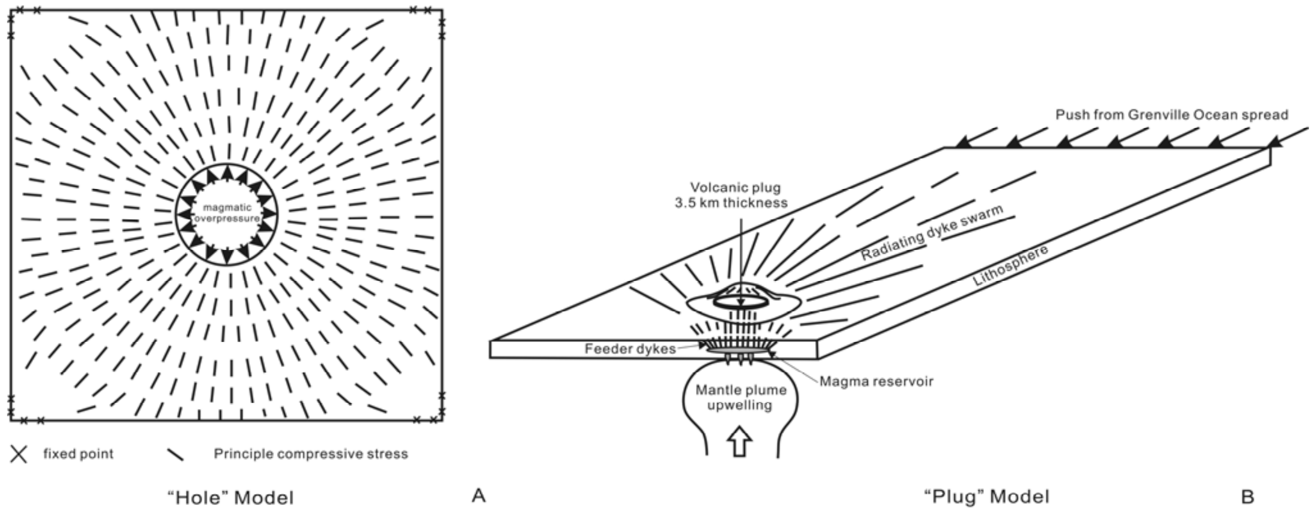

Fig. 2. Two mechanics models for the radiating dyke swarms. Model A-mechanics for small scale radiating dyke swarms related to volcanic edifice; Model B-mechanics for giant fan-shape dyke swarm related to mantle plume and ocean ridge.

around the magmatic focal area (boundary of Coppermine Lava) and a regional stress field far from the focal area, induced by opening of the, Grenville Ocean (ridge push) (Fig. 2B).

Since giant radiating dyke swarms and rifts developed in most of the cratons on Earth during the 1.3-1.2Ga periods, it can be suggested that these cratons were connected together in supercontinent Columbia, and that a supercontinent-wide extension event initiated its final breakup in the Late Mesoproterozoic (Zhai et al, 2003; Zhao et al., 2004; Hou et al., 2008a,b). After the final global breakup, Columbia was fragmented into separated continental blocks during 1.2-1.3 Ga. The giant radiating Mackenzie dyke swarm of 1.2-1.3 Ga is related to a super mantle plume below the Canadian Shield, and suggests that the upwelling of mantle plume and Grenville Ocean spreading both contribute to the final breakup of Columbia supercontinent.

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