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Giant Circumferential Dyke Swarms on Earth: Possible Analogues of Coronae on Venus and Similar Features on Mars

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Venusian coronae are large (60 - 2600 km diameter) tectono-magmatic features characterized by quasi-circular graben-fissure systems and topographic features such as a central dome, central depression, circular rim or circular moat. Similar features are observed in association with volcanic edifices in the Tharsis and Elysium regions of Mars. It has been proposed that the graben-fissure systems on both planets are underlain by dykes. If so, they may be analogues of giant circumferential dyke swarms on Earth, several of which have been recently identified (e.g. Buchan and Ernst 2016). In this study, giant circumferential dyke swarms are catalogued based on our research (except where otherwise referenced) and their characteristics compared with those of Venusian coronae (e.g., Bethell et al. 2016) and similar features on Mars.

For this study, we define giant circumferential swarms as swarms with a primary geometry that is roughly circular or elliptical and can be traced over an arc of $\geq 45^0$, and with a diameter ≥60 km. Some circumferential swarms are associated with giant radiating dyke swarms of similar age. As giant radiating swarms are typically interpreted to focus above mantle plumes and often focus along rifted margins, it is reasonable to assume that circumferential swarms associated with radiating systems are also linked to plumes and rifting. When a radiating swarm is not present, a link to a plume and rifting is less certain.

The largest giant circumferential swarm that has been identified is associated with the 125-80 Ma High Arctic Large Igneous Province (HALIP) which extends from the Arctic islands of Canada, across northern Greenland, to Svalbard and Franz Josef Land. It has a diameter of ~1700 km and an arc ~180^0, and is the first to be recognized by means of a continental reconstruction. Its centre is offset ~200 km from the focus of an associated HALIP giant radiating swarm. The relative age of the circumferential and radiating swarms is unclear as conflicting crosscutting relationships have been reported.

The Lake Victoria circumferential swarm (Mäkitie et al. 2014; Ruotoistenmäki 2014) of the 1380 Ma Kunene-Kibaran LIP in East Africa has a diameter >600 km and an arc of 160^0. The "dykes" have been described as vertical on the basis of field study or inward-dipping "cone sheets" based on geophysical modelling. There is no associated radiating swarm, although coeval sills, layered intrusions and granitoids are located within the swarm.

The Kochikha dykes of the 250 Ma Siberian Trap LIP appear to form a giant circumferential swarm with an elliptical shape (300-600 km diameter). Its centre is near the focus of a giant radiating swarm consisting of the Ebekhaya and Maimecha dykes and feeder zones to volcanic flows of the Noril'sk area. Kochikha circumferential dykes are younger than Ebekhaya and Maimecha radiating dykes based on cross-cutting relationships.

The 950 Ma Blekinge-Dalarna dykes of Sweden form a giant circumferential swarm (~1000 km diameter) that follows the edge of the high-grade Protogine Zone over an arc of ~60^0. Paleomagnetic directions along the swarm indicate that the arcuate geometry is primary. Slightly younger (935 Ma) Goteborg dykes could form part of a radiating swarm.

The ca. 130 Ma Ponta Grossa, Santos-Rio de Janeiro and Florianópolis dyke swarms of Brazil form three arms of a radiating system associated with the Paraná-Etendeka LIP. Each crosscut at a high angle by subsidiary dykes of similar or slightly younger age, which could represent portions of a circumferential swarm centred near the mantle plume responsible for the LIP or near the focus of associated triple-junction rifting related to opening of the south Atlantic Ocean.

In addition to giant circumferential swarms, there

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are cases of possible segments of circumferential swarms, where short swarms without a clear arcuate pattern crosscut roughly coeval radiating swarms at right angles. For example, the Clarence Head swarm of the 720 Ma Franklin LIP in northern Canada has been proposed as a segment of a circumferential swarm (Denyszyn et al. 2009). It is located >1000 km from the focus of the radiating Franklin swarm and appears to be slightly younger than the radiating dykes. The ca. 1780 Ma Lüliang swarm of the North China Craton is perpendicular to approximately coeval dykes of the giant radiating Taihang swarm and could form a component of a circumferential swarm with a diameter of ~1200 km.

Terrestrial giant circumferential dyke swarms typically have characteristics similar to those of Venusian coronae or similar features on Mars. They are quasi-circular/elliptical with a wide range of diameters (up to 1700 km). By comparison, the largest corona on Venus has a diameter of 2600 km. On all three planets there is often an associated giant radiating system. The centres of the circumferential and radiating systems may coincide or may be offset.

Although, where evidence is available, the circumferential component is more likely to be younger than the radiating component on both Earth and Venus, there are also cases where the age relationship is more complex and may require multiple pulses of either radiating or circumferential dyke emplacement.

Venusian coronae and similar features on Mars are typically associated with circular topographic features. Although such features may have been present when circumferential dyke swarms intruded on Earth, they will likely have been lost to erosion, which is severe on Earth and almost absent on Venus. Little investigation has been conducted to determine if such paleo-topography is detectable in the terrestrial sedimentary record.

As noted above, giant circumferential swarms that are linked to radiating swarms are likely also related to mantle plumes and rifting. Similarly, on Venus, coronae are usually attributed to an underlying plume or diapir, and in the BAT region, are often associated with rift systems.

In conclusion, terrestrial giant circumferential dyke swarms have many of the characteristics of Venusian coronae and comparable features on Mars. This suggests that they may have similar origins.

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