LIPs and implications for the structure and evolution of continental crust

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Large Igneous Provinces

Large Igneous Provinces (LIPs) have broad significance for a number of areas of geology. LIPs are important in constraining paleocontinental reconstructions (e.g. via magmatic barcodes, Bleeker and Ernst, 2006; Ernst and Bleeker 2010; and via paleomagnetism, Buchan 2014), are a new tool in resource exploration targeting (e.g. Ernst and Jowitt, 2013), are analogues for planetary intraplate magmatism (e.g. Head and Coffin, 1997; Ernst, 2014), and have a causal role in dramatic climate change throughout Earth history (Ernst and Youbi, 2017).

Here we highlight how LIPs are useful in revealing the structure and evolution of continental crust. We consider four aspects: 1) identification of mantle plumes and resulting modifications of the overlying lithospheric mantle and crust, 2) interpretation of regional stress patterns and mapping of deformation zones, and 3) tracking of subduction-caused metasomatism of lithospheric mantle and lower crust. 4) characterizing large shallow and mid-crustal layered intrusions in order to better understand deep crustal deformed and metamorphosed layered intrusions.

Locating Mantle Plumes

Mantle plumes arriving beneath continents can cause profound changes on the geology and geophysical response of the overlying lithospheric mantle and crust. The most successful method for locating paleo-mantle plumes is using regional dyke swarms of LIPs. Specifically, giant radiating swarms (with radii of up to more than 2500 km) focus on the plume centre region (Ernst and Buchan 1997). In addition, the newly discovered class of giant circumferential swarms can mark the outer edge of the plume at a radius of about 1000 km (Buchan and Ernst, 2018a,b).

Recognition of mantle plumes is significant for continental crust for many reasons including the following: 1) as a locus of lithospheric thinning and continental breakup (or attempted, but failed breakup) (Courtillot et al. 1999; Ernst and Bleeker 2010); 2) for locating the central region (within about 500 km of the plume centre) that is the locus of a magmatic underplate and intracrustal intrusions (Blanchard et al. 2017; Ernst et al. 2018); 3) providing constraints on deep geophysical interpretations based on a knowledge of the LIP plumbing system (Ernst et al. 2018); and 4) Influence on resource exploration for ore deposits and oil/gas (Ernst and Jowitt, 2013)--- for instance, to predict regions in which heat from the plume destroyed diamond potential in the overlying lithospheric mantle root.

Revealing region stress patterns and local deformation

Here we discuss the implications of LIP events for tracking regional stress patterns and mapping deformation zones.

Dyke swarms can radiate out to the edge of the mantle plume (1000 km) and then swing into a regional stress direction (Ernst and Buchan 1997). Present-day regional stress fields are consistent throughout large intraplate areas, and are caused by plate-boundary stresses (partly controlled by the orientation of spreading ridges). Therefore, the geometry of large dyke swarms can potentially reveal the orientation of paleo-spreading ridges.

Regional dyke swarms (belonging to LIP events) that predate and extend across a deformation zone can be used to map the deformation pattern. For example, a sigmoidal flexure in the overall radiating pattern of the c. 2460 Ma Matachewan swarm/LIP (southern Superior craton) was used to constrain the deformation history of the c. 1900 Ma Kapuskasing Structural Zone (Evans and Halls, 2010).

Mapping regions with modified lower crust and lithospheric mantle

Silicic magmatic provinces (associated with LIPs), can be produced by melting of fusible lower crust due to heating by a mantle plume. For example, it is inferred that 183 Ma pulse of the Chon Aike silicic province (South America) is caused by a portion of the 183 Ma Karoo-Ferrar plume arriving beneath fusible lower crust (e.g. Bryan and Ferrari, 2013; Ernst, 2014). Therefore, the distribution of LIP-associated Silicic provinces can identify regions of lower crust that were metasomatized during an earlier subduction event.

Mafic units of many LIPs exhibit a weak subduction geochemical signature (negative Nb anomaly) that is generally interpreted to have been acquired during contamination of LIP magmas by metasomatized lithospheric mantle or by crustal contamination. While silicic magmas are fed vertically, mafic magmas (especially as dykes) can be transported laterally from a plume centre region for up to 2000 km or more (e.g. Ernst and Buchan 1997). This implies that the contamination (by metasomatized mantle or crust) can occur a long distance from the mafic unit showing that contamination. Therefore, in order to link the observed chemistry of LIP units to appropriate sections of continental crust and lithospheric mantle, it is essential to understand the plumbing system of LIPs (Ernst et al. 2018)

Magma chamber characteristics

It is important to study undeformed and unmetamorphosed shallow and mid-crustal magma chambers such as the Bushveld intrusion (that are associated with LIPs), in order to better understand the huge deformed magma chambers in the deep crust, some of which can represent magmatic underplate associated with plume/LIP events.

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