GEOTECTONIC CONSIDERATIONS ON PRIMARY DIAMOND SOURCES IN MOBILE BELTS

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"Clifford's Rule" which states that economically viable kimberlites are restricted to cratonic areas has been shown to be valid world-wide (Janse, 1994). The discovery of Argyle has shown that economically viable lamproite can occur in Early Proterozoic mobile belts. At the same time the minimum age of the basement conducive to economically viable kimberlite and lamproite intrusion shifted from 1500 Ma (Clifford, 1966) to 1800 Ma. Helmsteadt and Gurney (1994) emphasized that the economic viability of kimberlites and lamproites is related to the preservation of Archean mantle roots. Gurney and Harris (1994) concluded that Clifford's Rule is valid because deep lithospheric mantle is more likely to be preserved underneath very ancient, i.e. 3.2 Ga old, cratonic areas. Gonzaga et al., (1992) stated that the restriction of economically viable kimberlites and lamproites to specific geotectonic environments and age is the result of global evolution of the earth's lithosphere. The authors linked the occurrence of economic primary sources to the thermotectonic evolution of the area: kimberlite or lamproite may be strongly mineralized in long lived stable areas (cratons) or in ensialic Early (or eventually Middle) Proterozoic mobile belts that present low geothermal gradients.

High-Grade Diamond Mineralization in Mobile Belts

Examples of diamond mines in mobile belts are Venetia and River Ranch in the Limpopo Belt and Argyle in the Halls Creek Belt. Some authors consider the Limpopo Belt as a continental collision orogen (Treolar et al., 1992) others as an accretion belt (Rollinson, 1993), but there is evidence that the Limpopo Belt consists mainly of reworked Archean crust (Van Breemen, 1970). White and Smith (1994) showed that the King Leopold and the Halls Creek belts (in which the diamondiferous Ellendale and Argyle lamproites occur) were subjected to a high grade metamorphic event in the Barramundi Orogeny (1.85 Ga) and are underlain by ancient peridotitic lithosphere of Archean or Early Proterozoic age. These diamondiferous lamproites thus fit into the concept of an ancient cratonic setting similar to the distribution of diamondiferous kimberlites in Africa as noted by Clifford (1966). It can therefore be concluded that the existence of a lithospheric keel of Archean age beneath a mobile belt determine the economic potential of the kimberlite and lamproite host in it. The preservation of such keel depends on the subsequent geotectonic regime of the mobile belt. Formation of ocean crust, collision and subduction zones, magmatic island arcs, etc., will cause a change in the geothermal gradients (Gonzaga et al., 1992), and may result in the delamination and thermal destruction of the lithosphere keel during the evolution of mountain belts

Low-Grade Diamond Mineralization in Mobile Belts

The genesis of diamond in cratonic areas is well constrained. It is generally accepted that high grade diamondiferous kimberlites are restricted to stable, thick, cool, and depleted lithospheric keels. The rigidity and persistence of cratons are linked to the presence of a thick mechanical boundary layer whose growth requires quiet conditions during several hundred Ma - a necessary condition for large diamond formation (Pearson et al., 1994). Constraints of oxygen fugacity, mantle metasomatism, and preservation of diamonds will not be discussed here. It is well known that diamond occurrences in kimberlite and lamproite in Proterozoic mobile belts are characterized by low-grade mineralization. The origin of diamonds in these environments, however, has deserved little attention. It is proposed in this paper that low-grade diamond mineralization could result from the following geotectonic processes:

1 - Partial preservation of cratonic lithosphere.
The mechanism of preservation of Archean lithosphere underneath mobile belts is exemplified by the Limpopo and Halls Creek belts, which contain, however, high-grade diamond mineralization. It seems that

this kind of evolution was restricted to Late Archean and Early Proterozoic. Smaller degrees of preservation may provide less favorable, but still present, conditions for diamond survival or formation underneath mobile belts all over the world. This would result in smaller and variable abundance of diamond that can be sampled by kimberlite and lamproite, resulting in low-grade mineralization (e.g. Rio Negro-Juruena Belt, Brazil).

2 - Subduction of oceanic slabs.
Diamond formation during subduction of oceanic lithosphere has been proposed by several authors (e.g. Schulz, 1986; Kesson and Ringwood, 1989; Sobolev and Shatsky, 1990). With subduction, portions of a descending slab are submitted to pressure and temperature conditions compatible with the diamond stability field (Barron et al., 1994). The diamond occurrences in ophiolites would represent obducted examples of these slabs (e.g. Beni Busera, Luobosa and Donqiao). Accordingly, it seems that the subduction would allow widespread nucleation of diamond crystals, that consequently would not grow large. These diamonds may survive or not depending on the characteristics of latter tectonic processes. Slab fragments with some diamond can remain inside and underneath the belts and be sampled by kimberlite or lamproite. The detailed formation mechanism and the fate of slab-derived diamonds remain questionable.

3 - Thermal erosion and local lithospheric thickening
Houseman et al. (1981) proposed a model for orogenesis evolution in which a convection cell in the asthenosphere causes erosion of the thermal boundary layer. In each side of the cell, portions of the lithospheric mantle sink into the asthenosphere originating temporary lithosphere roots. This process allow that in these relatively cool downwelling portions of mantle, PT conditions be compatible to the diamond stability field. We have no direct evidence, so far, whether diamond forms or not in this situation.

4 - Uplift, erosion, lowering of geothermal gradient and localized lithosphere thickening
In a review about the temperature distribution in the mantle and the crust, Jeanloz and Morris (1986) developed a model that relates variation of geothermal gradients to uplift and erosion. This process represents a combination of heat conduction and advection. This combination results in a very efficient mechanism of heat transfer from depth to the surface: the conduction occurs in a part of the crust that is moving upwards - and consequently transporting heat from depth. The consequence is an increase in the surface heat flow and a decrease of temperature in depth. The temperature decrease is directly proportional to the uplift velocity. The authors cite that uplift rates of 0.03-0.5 mm/yr have been recorded in many localities and that rates as high as few millimeters per year are occasionally reported. They state that corrections of up to 500°C for temperature at the base of the crust may well be required. Tectonically raised portions of the crust would have lower geothermal gradients than its surrounds. Uplifted blocks, horsts, domes, tectonic arcs, etc., are candidates to present such a feature. Uplift is common in rifts, where geothermal gradients are high. The intense magmatism and fluid circulation associated to rift systems are mainly responsible for the observed high heat flow (Morgan, 1983; Jessop, 1990). Jessop (1990, pg 183) states that "models of lithospheric thinning and uplift during the rift process suggest that generally high heat flow would not be expected over young rifts, because of the time required for heat flow at the surface to react by conduction to temperature changes at the lithosphere". There is some evidence that uplifted areas may posses heat flow similar or lower than those in cratons. Morgan (1983) shows that, with some exceptions, the broad domal or plateau uplifts associated to rift systems present low to normal heat flows. In the East African Rift System some measurements gave 22 - 38 mW/m^2. It is known that portions of mobile belts that are characterized by higher seismic frequency then their surroundings have very low heat flows. One example is the João Câmara region in northeast Brazil with 25 mW/m^2 (Carneiro et al., 1989). An "island" of colder lithosphere would have different rheological, thermodynamic, and compositional properties. It is possible to envisage that such a portion of the lithosphere, possibly undergoing uplift as a fault block, could raise the upper boundary of the diamond stability field giving rise to the nucleation of diamond; provided that carbon, oxygen fugacity, etc., are within the necessary constraints. Some examples of kimberlite and lamproite that contain low-grade diamond mineralization which occur in uplifted areas of mobile belts include: Kapamba lamproites (Zambia); Kundelungu kimberlites (Zaire); kimberlites from the State Line District (USA), etc.

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