DIAMOND POTENTIAL IN BRITISH COLUMBIA, CANADA?

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INTRODUCTION

The main objective of this paper is to describe the possible significance of the reported microdiamond /diamond occurrences in British Columbia (BC) and assess BC's diamond potential, in terms of traditional "deep keel" and controversial "subduction zone" diamond stability environments. Geological diamond potential of BC in terms of unconventional diamond host rocks, that until recently were not believed to have a potential as a diamond host, may also warrant some reassessment.

TECTONIC SETTING OF BC ALKALINE PROVINCE:

The BC Alkaline Province is located on the western margin of North America, within Canadian Cordillera. Tectonic setting of BC can be described in terms of the North American continent, adjacent pericratonic and displaced terranes, and accreted superterranes. The Canadian Cordillera is located on the ocean-continent boundary since a supercontinent called Rodinia started to rift apart, more than 530 Ma ago (Price and Monger, 2000). At that time Panthalassa (the ancestor of the present Pacific Ocean Basin) started to form. The subduction along the western margin of North American craton started about 390 Ma ago and since that time a large proportion of the Pacific Ocean Lithosphere disappeared beneath North America. Cache Creek, Wrangellia and Alexander are interpreted as very far traveled terranes (Price and Monger 2000; Monger and Nokleberg, W.J., 1996). Quesnellia, Stikinia and Slide Mountain terranes are considered as ancient portions of the North American plate, but they were displaced relative to their current position at the margin of the North American Craton. Pericratonic terranes are those that formed near the craton and some of them were displaced.

GEOLOGY OF THE BC ALKALINE PROVINCE

BC's alkaline province is belt-shaped and it approximately follows the margin of the North American continent. It consists of a variety of rocks, including lamproites (McCallum, 1994); carbonatites, kimberlites, alkaline complexes, syenite gneisses (Pell, 1994) and wide variety of lamprophyres (Ijewliw, 1991). Of particular interest to the diamond exploration community are four major ultrabasic diatreme/dyke clusters. The Northern clusters (Ospika River and Kechika), central cluster (Golden) and southern cluster (Cranbrook) were previously described by Ijewliw (1991), Pell (1994) and Helmstaedt et al., (1988). The lithology of these ultramafic dykes and diatremes varies widely and includes calc-alkaline and alkaline lamprophyres, possibly limburgites, olivine mellilitites, lamproites and kimberlites (Ijewliw 1991, McCallum (1994) and Pell, 1994) and rocks of basaltic affinity. A variety of basaltic and ultramafic dykes and lamprophyre rocks within the province were reported outside of these clusters, but these occurrences were neither compiled nor studied in detail.

AGE OF DIATREMES AND DYKES

Ospika pipe cuts middle Ordovician rocks (Rb/Sr date 334±7 Ma; K/Ar 323±10 Ma). Diatremes of the Golden cluster cut Upper Cambrian rocks and are believed to be Late Silurian to Early Devonian in age (Mica - Rb/Sr 409±6 Ma and K/Ar 391±5Ma). They lie below a Middle Devonian unconformity (Ijewliw 1991). Cross Kimberlite Rb/Sr dates on phlogopite are 240-250 Ma (Grieve, 1982; Smith *et al*., 1988). Parish and Reichenbach (1991) sampled a number of diatremes including Cross, Blackfoot and Joff in the Cranbrook cluster and Jack, Mark, Mike and HP for U-Pb dating. Obtained dates varied from

2.7 Ga to 440 Ma. These ages and variations are not believed to represent ages of diatremes. The pipes contain both mantle and crustal xenoliths. The zircon xenocrysts were probably derived from a combination of sources including basement gneisses and local intrusive rocks. Some of the zircons may have been originally liberated by weathering from the western Canadian Shield, shed westward and incorporated into pericratonic terrains. The stratigraphic evidence suggests that diatremes of the Cranbrook area were emplaced during several pulses, prior to Late Devonian unconformity (Pell, 1994; Helmstaedt *et al*., 1988).

HIGH PRESSURE METAMORPHIC ROCKS AND ALKALI BASALTS

These two groups of rocks are not known to carry diamonds in British Columbia, however they host diamonds in several localities around the world. More importantly, they are also key supporting elements for the "ES-diamond Model". High-pressure (blue schist-and eclogite-facies) rocks, interpreted as subduction zone related, are known along the margin of Ancestral North America, from Alaska to Mexico (including BC). Their isotopic ages, range from 37 to 447 Ma (Late Cretaceous to Middle Paleozoic (Erdmer *et al*.1998), however, at this stage it is not clear if these dates represent peak metamorphic conditions or later cooling or re-setting. Alkali basalts contain mantle xenoliths (Fuji and Scarfe, 1982; Mitchell, 1987; Peslier, 1998), mainly spinel lherzolite and much less abundant olivine websterite, websterite, clinopyroxenite and wehrlite. Both high-pressure metamorphic rocks and alkali basalts are located west of the alkaline province. It is possible that even some of the ultrabasic diatremes within BC's alkaline province, as described earlier, may be subduction related or may have intersected the rocks that were previously in the diamond stability field.

DIAMOND OCCURRENCES IN BC

Microdiamonds were reported in samples from Jack (Lens Mountain) and Mark (Valenciennes River) diatremes (Northcote, 1983a,b). These Diatremes are part of Golden Cluster. A single microdiamond was reported from a poorly described breccia within the Xeno carbonatite complex, which is located within the Kechika area (Roberts, 2002). This locality was explored mainly for REE, Nb and Ta. Macrodiamonds were also reported within the Cranbrook cluster, from Bonus (Allan, 1999) and Ram 5 and 6 pipes by Consolidated Ramrod Gold Corporation, exploration predecessors of Skeena Resources Limited (Allan, 2002 and George Cross News Letter, 1994), however no microdiamonds were recovered from 143 metres of split NQ core drilled by Skeena that intersected the Ram-6 pipe (Allan, 2002). There is little public information about the morphology of the recovered BC micro-diamonds and the inclusions that they may contain. Nitrogen content and isotopic composition of diamonds is not known, so the speculation about their origin is not constrained. Indicator mineral data is covered mainly in assessment reports of the BC Ministry of Energy and Mines and in Fipke et al. (1995). Studies of indicator minerals, in a number of ulrabasic diatremes, suggest that they originated within or near the diamond stability field as expected under the "diamondiferous mantle root model". Up to now, only the Cross pipe is officially confirmed as true kimberlite, but it is possible that Bonus and Ram 5 and 6 diatremes may turn out to be kimberlites as well. Peace River Arch area, which attracted few minor staking diamond rushes over the last few years remains active but no diamonds or microdiamonds were reported up to know.

DIAMONDIFEROUS MANTLE ROOT MODEL

The present tectonic setting of the diamond occurrences in BC does not match the traditional "deep keel" or " diamondiferous mantle root model" as described by Haggerty (1986), Boyd and Gurney (1986), Mitchell (1991). Classical diamond producing areas are located within stable cratons and not surprisingly, Cordillera would not be rated as highly prospective for diamonds if Clifford's Rule, as described by Janse (1994a), is strictly applied. If BC’s diamond occurrences have to be explained by the "deep keel" hypothesis, then we have two possible avenues to follow. The basement rocks of similar age and nature as those that underlie the diamondiferous and potentially economic kimberlites occurrences in Alberta may extend into eastern BC. Alternatively, since the tectonic

history of British Columbia through geological time is very complex, there is a possibility that British Columbia may have been underlayed by a "deep keel" in the past. For example, extensional tectonic regime and rifting within Rhodinia is believed to have started 750 Ma and then again in Late Proterozoic to Early Cambrian (550-530 Ma). This activity was followed by sea floor spreading (separation of Rhodinia), initiation of proto-Pacific Ocean, by deposition of miogeosynlinal sediments and ultimately by a long lasting and evolving subduction regime. If this is correct, then 750 Ma ago the west coast of BC, was matched with the Eastern Australia (Dutch 2002) and conceivably it may have been underlain by a mantle root.

SUBDUCTION ZONE DIAMOND HYPOTHESIS

An other possible way to explain the origin of diamond occurrences in BC is in terms of "ES-Diamond Model" which was originally proposed by Barron *et al*. (1994) and considered for British Columbia by Simandl (1998). The main attraction of this model is created by the slope of diamond / graphite stability line on P-T diagram. Studies describing metamorphic and P-T-t conditions and thermal modeling as related to subducting slab incorporate variables such as angle of subduction, length and thickness of the UPH fragment, heat flow rate, convergence (subduction) and exhumation rates, shear heating and convection of subcontinental mantle (Ponco and Peacock 1995; Roselle and Engi, 2002) suggest much cooler isotherm (500-600ºC at 100km depth) within the subducting slab than what would be expected for the continental near the "mantle root area", where temperature may be in the 1000-1400ºC range at depth of 100 km. Depending on the parameters, such modeling exercises indicate that the diamond stability field could exist in subduction zone setting. Discovery of microdiamonds in ultra high pressure UPH metamorphic rocks in Dabie Shan Mountains in China (Xu *et al*., 1992), in ophiolites (Bai, 1993) and in variety of metamorphic rocks (garnet-biotite gneiss, dolomitic marble and garnet-kyanite-phengite-quartz schist within Kokchetav massive in Northern Kazachstan (Kytayma et al., 2001) demonstrate that the diamondiferous mantle root model is not required to form diamond. The validity of this model in exploration still remains to be proven.

OTHER UNCONVENTIONAL TYPES OF DIAMOND OCCURRENCES AND PLACERS

For an excellent compilation of unconventional diamond occurrences, worldwide, see Janse (1994b). The discovery of diamonds in ophiolitic assemblages, such as those in Tibetan ophiolites described by Bai *et al*., (1993) may be particularly relevant to BC. Diamond placer or paleo-placer potential of British Columbia was not seriously considered either, since it is dependent on the potential sources of primary diamond deposits.

DISCUSSION AND SUMMARY

The "diamondiferous mantle root model" remains the workhorse of the diamond exploration community and it directs the flow of exploration money. However, since the discovery of the lamproite-hosted Argyle Mine, the exploration community is more open to look at "off-craton" localities especially Mobile Belts. Recent discoveries of potentially economic diamond occurrences in non-traditional geological lithologies in Ontario, unexplained alluvial diamond occurrences in the Western USA and Alaska and reported diamond occurrences in BC, near the NWT -Yukon border, and near the west coast of Alaska indicate that exploration geologists should keep an open mind. They should be ready to use paleo-tectonic data to find location of ancient diamondiferous mantle roots that may not exist anymore, but may have been intercepted by diamond transporters such as kimberlites and lamproites in the past. New models (including the controversial "ES - Diamond Model") should not be discarded without careful consideration. Probably, the ideal starting point in the evaluation of the British Columbia's diamond potential would be to independently confirm all the reported diamond occurrences in BC, to eliminate any possibility of contamination (unless diamonds in higher concentrations are found). Recovered diamonds should be physically, chemically and isotopically characterized, their inclusions and related indicator minerals systematically studied and documented and interpreted to see if it is in line

with "diamondiferous mantle root model", Argyle setting, "ES-diamond Model" or if an alternative hypothesis is required. Depending on results, the interest in diamond exploration in the province may be enhanced and exploration future exploration better focused.

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