^{3}He and ^{10}Be Isotopes as a Diamond Exploration Tool: Some Thoughts Based on Literature Data

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Cosmogenic ^{3}He can be produced in diamonds during their post-eruptive residence near the surface (Lal, 1987). Cosmogenic ^{3}He production is not expected bellow 5 meters below the surface in alluvium or weathered kimberlite or lamproite pipes (Lal et al., 1989). ^{10}Be has a half life of $1.5x10^6$ years and can be used to date the exposure time to cosmic rays, but a saturation level can be reached limiting the time interval in which ^{10}Be can be used. Saturation depends on the material, latitude, and altitude and is typically reached in several million years. Unlike ^{10}Be, ^{3}He however, will continue to accumulate in the diamond (Lal et al., 1987).The geomagnetic field also affects the production rates of both isotopes. Despite all these variables some data in the literature suggest that it could be possible to use ^{3}He and ^{10}Be to study the exposure history of diamonds (Cerling and Craig 1994).

Several determinations of noble gases isotopes, in particular ^{3}He and ^{4}He, are available for diamonds from worldwide occurrences. The data are on alluvial, pipe and undocumented stones. In order to evaluate de ^{3}He content of documented specimens we compare alluvial and pipe diamonds occurring in South Africa (Premier, Finsch), Botswana (Orapa), Zaire, Sierra Leone and Australia (Argyle and Ellendale).

Alluvial and pipe diamonds were analyzed by Ozima *et al* (1983); Ozima *et al* (1985); Lal *et al* (1987); Honda *et al* (1987); Kurz *et al* (1987); Lal *et al* (1989); McConville and Reynolds (1989); McConville *et al* (1991) and Wiens *et al* (1994). ^{3}He contents of several diamonds and sample discrimination for alluvial and pipe are presented in Figures 1, 2 and 3. Ozima *et al* (1983) found high ^{3}He content in inclusion-free diamonds from the Premier Mine (depth not specified) and proposed a primitive signature for the high ^{3}He/^{4}He ratio. Lal *et al* (1987) presented ^{3}He content for two alluvial stones in Zaire and compared to other determinations for Zaire alluvial diamonds from Ozima *et al* (1985) and Honda *et al* (1987). The high ^{3}He content observed was attributed to cosmogenic origin. The same cosmogenic component was also suggested to occur in alluvial diamonds from South Africa that present high ^{3}He content when compared to pipe ones (Lal *et al*, 1989). Diamonds from the Premier Pipe yield low ^{3}He content and contrast with the preliminary analysis from Ozima *et al* (1983). The authors also analyzed diamonds from the weathered zone of the Argyle pipe and from a nearby alluvium. In contrast, both samples displayed low ^{3}He contents. McConville and Reynolds (1989) examined fragments of two stones from the Sierra Leone alluvial. One stone is inclusion-free (L_4 and L_5) and the other contain inclusions (L_6, L_7 and L_8). The ^{3}He content is high for both stones but the ^{4}He content is much lower for the first group (L_4 and L_5). The higher ^{4}He content for the second group was assigned to the decay of U and Th in the inclusions. McConville *et al* (1991) examined diamond specimens from the weathered zone of the Argyle Pipe, from a 2,9 km distant alluvium (Limestone Creek) and from the Ellendale Pipe (Australia). In contrast to the low ^{3}He and ^{4}He values found by Lal *et al* (1989) for the Argyle pipe and alluvial diamonds, the authors report much higher contents of both isotopes in diamonds from the same places. They believed that the differences are due to an U-free phase analyzed by Lal *et al* (1989), yielding low ^{4}He values. Diamonds from the Ellendale pipe show lower ^{3}He values. Kurz *et al* (1987) examined diamonds from the Orapa Kimberlite in Botswana through step analysis. The authors found variability within single stones and attributed it to U and Th zonation and/or surface implantation. The samples were recovered from 40 meters deep what did not allow cosmogenic ^3He production. The authors drew attention to the fact the the one step analysis usually presented in the literature would hide isotope variability.

The results of Lal *et al* (1987) and Lal *et al* (1989) are plotted separately from those of McConville and Reynolds (1989) and McConville *et al* (1991) in Figures 2 and 3. The most important feature, common to both diagrams, is that the ^3He contents of alluvial diamonds are higher than those in pipe diamonds. The absolute values, however, do not show consistency between the two data sets (see Figure 1). The differences in absolute values could be due to different laboratory procedures.

The data presented in Figures 2 and 3, thus, suggest that ^3He contents in diamonds seem to be a potential tool to identify and discriminate diamonds with a long, short or no exposition time to cosmic rays, mainly, if combined to the calculated ^{10}Be exposure times. The results that both isotopes (and perhaps others) can provide are directly related to the time interval that a diamond population has been involved, or not, with sedimentary recycling. Examples of diamond prospecting areas where this exploration tool could be tested include the Casuarina (Australia), Guanyamo (Venezuela), São Francisco Craton (Brazil), etc. The field of cosmogenic isotopes studies for diamond exploration programs seems to be open and promising, if well controlled target areas are chosen and methods and specific criteria are established.

References

Cerling, T.E., and Craig, H., 1994, Geomorphology and in - situ cosmogenic isotopes: Annu Rev, Earth Planet. Sci., v.22, p.273-317.

Honda, M. and Reynolds, J.H., 1987, Noble gases in diamonds: occurrences of solarlike helium and neon: Jounal of Geophysical Research., v.92, p. 12507-12521.

Kurz, M.D., Gurney, J.J., Jenkins, W.J., and Lott III, D.E., 1987, Helium isotopic variability within single diamonds from the Orapa kimberlite pipe: Earth Planet. Sci. Letters., v.86, p. 57-68.

Lal, D., 1987, Production of ^3He in terrestrial rocks: Chemical Geology (Isotope Geoscience Section)., v.66, p. 89-98.

Lal, D., Craig, H., Wacker,J.F., and Poreda, R., 1989, ^3He in diamonds: The cosmogenic component: Geochimica et Cosmochimica Acta, v.53, p. 569-574.

Lal, D., Nishiizumi, K., Klein, J., Middleton, R., and Craig, H., 1987, Cosmogenic ^{10}Be in Zaire alluvial diamonds: implications for ^3He contents of diamonds: Nature, v. 328, p.139-141.

McConville, P., and Reynolds, J.H., 1989, Cosmogenic helium and volatile-rich fluid in Sierra Leone alluvial diamonds: Geochimica et Cosmochimica Acta, v.53, p.2365-2375.

McConville, P., Reynolds, J.H., Epstein, S., and Roedder, E., 1991, Implanted ^3He, ^4He, and Xe in further studies of diamonds from Western Australia: Geochimica et Cosmochimica Acta, v.55, p. 1977-1989.

Ozima, M., Zashu, S., Mattey, D.P., and Pillinger, C.T.,1985, Heliun, argon and carbon isotopic compositions in diamonds and their implications in mantle evolution: Geochemical Journal, v.19, p. 127-134.

Ozima, M., Zashu, S., and Nitoh, O., 1983, $^3He/^4He$ ratio, noble gas abundance and K-Ar dating of diamonds - an attempt to search for the records of early terrestrial history: Geochimica et Cosmochimica Acta, v. 47, p. 2217-2224.

Wiens, R.C., Lal, D., Rison, W., and Wacker, J.F., 1994, Heliun isotope diffusion in natural diamonds: Geochimica et Cosmochimica Acta, v. 58, p. 1747-1757.

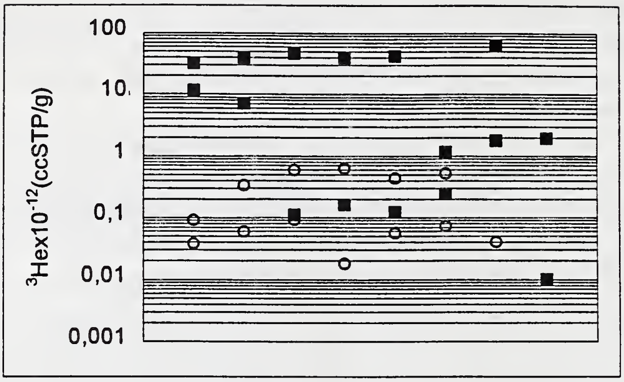

Figure 01 - Alluvial (filled symbols) and pipe (open symbols) diamonds reported by Lal *et al*, 1987; Lal *et al*, 1989; McConville and Reynolds, 1989 and McConville *et al*, 1991.

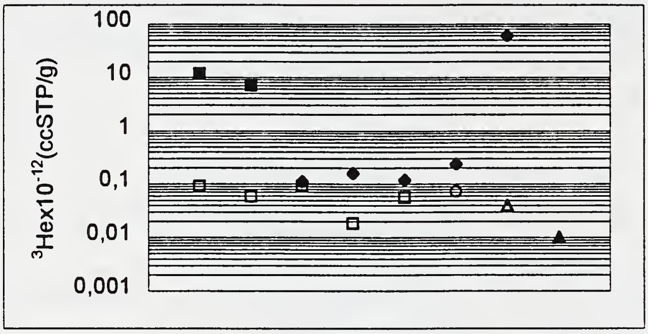

Figure 02 - Open symbols: pipe diamond; filled symbols: alluvium diamonds. Data from Lal *et al* (1987) and Lal *et al* (1989). Filled square - Zaire alluvium, samples EBM and Zaire-1 (Lal *et al*, 1987); filled losangle - Namibian alluvium, samples CDM-1 to CDM-5; filled triangle - Argyle near alluvium, sample ARG-AI-1; open square - Finsch, Premier and De Beers Pool Mine South African pipes, samples FNS-1, FNS-2, PR-1, PR-2 and D.P.; open circle - Panna Pipe, India, sample P1; open triangle - Argyle Pipe, Australia, sample ARG-P-11 (Lal *et al*, 1989).

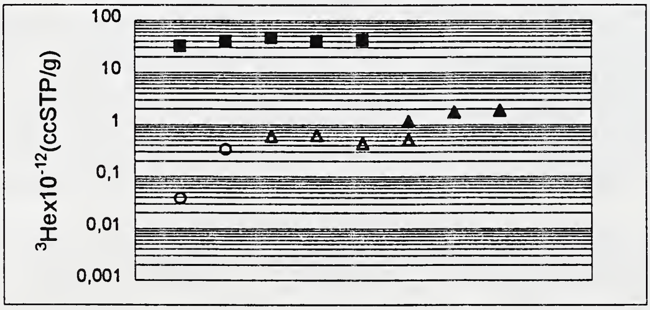

Figure 03 - Open symbols: pipe alluvium; filled symbols: alluvium diamonds. Data from McConville *et al* (1989) and McConville and Reynolds (1991). Filled square - Sierra Leone Alluvium, samples $L_{4\text{-}5}$, $L_{6\text{-}8}$ (MacConville and Reynolds, 1989); Filled Triangle - Argyle near Alluvium, Australia, samples LC-WZ, LC-Wg and LC-BZ. Open circle - Ellendale Pipe, Australia, samples ELL-WZ and ELL-YZ; Open triangle - Argyle Pipe, Australia, samples ARG-WZ, ARG-WG, ARG-BG#1 and ARG-BG#2 (McConville *et al*, 1991).