SEA FLOOR HYDROTHERMAL VENT SYSTEMS: PROTOENVIRONMENT FOR ^{13}C-DEPLETED ECLOGITIC DIAMOND

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Eclogitic diamonds have a carbon isotopic range of ~0 to -30‰ that may be accounted for by primordial mantle heterogeneities, or by crustal carbon introduced into the mantle via subduction. Mid ocean ridge basalt (MORB) is similar in composition to eclogite, but has been discounted as a protolith because carbon is a minor component in unaltered MORB and has an average $\delta^{13}C$ of around -6‰ (Deines, 1992). The alternative theory that ^{13}C-depleted eclogitic diamonds are due to primordial carbon heterogeneities in the mantle like those observed in carbonaceous chondrites is encumbered by the fact that chondrites have bulk compositions greatly different from eclogite (Kirkley et al., 1991). Proponents for subduction argue that ^{13}C-depleted carbon is obtained from other marine rocks such as continental carbonaceous shales (CCS; Kirkley et al., 1991). Unfortunately most of these rocks are in tectonic settings not prone to subduction, a limitation that those who favour the primordial carbon model are quick to point out (Deines, 1992). Arguments supporting either camp are based on isotopic or trace element studies that are often equivocal and subject to more than one interpretation (Jacob et al., 1994; Snyder et al., 1993).

A straightforward evaluation of the models has been carried out by comparing bulk compositions for diamond eclogites to the bulk compositions of carbonaceous shale and chondrites. The diamond eclogite composition include carbon content and are based on detailed microprobe and mineral abundance determinations (Robinson, 1979; McCandless and Gurney, 1986; McCandless and Collins, 1989; Sobolev et al., 1994). Observations that have emerged are that the composition of diamond eclogite cannot be obtained by bulk metamorphism of carbonaceous chrondrite or CCS. The alternative favoured by subduction proponents to move ^{13}C-depleted carbon from CCS into MORB via a fluid phase is also unacceptable. Up to 5% CCS added to MORB can produce diamond with $\delta^{13}C$ = -30‰, but the resultant mixture can not account for the high carbon content of some diamond eclogites without drastically shifting the product away from a diamond eclogite (i.e., basaltic) composition. MORB remains the best protolith for diamond eclogite; the requirement is that carbon with the necessary ^{13}C-depleted carbon composition must be introduced without affecting bulk MORB composition.

New studies reveal that MORB does in fact contain abundant ^{13}C-depleted carbon, from microbial activity in the vicinity of seafloor ridge hydrothermal vents (Delaney et al., 1994; Lilley et al., 1993) and could account for ^{13}C-depleted eclogitic diamonds (Nisbet et al., 1994). Seafloor ridge hydrothermal vents host a vast biosystem that depends directly or indirectly on chemosynthesis, deriving energy through chemical reactions with dissolved components in the hydrothermal fluids (Jannasch, 1989; McCollom and Shock, 1994). Mixing of MORB with ophiolitic shales enriched in ^{13}C-depleted microbial carbon (Loukola-Russkeeniemi et al., 1991) can account for the ^{13}C-depleted nature of eclogitic diamonds without changing the diamond eclogite product away from a basaltic composition. Up to 10% ophiolitic carbonaceous shales can be added to MORB to produce eclogitic diamond with $\delta^{13}C$ = -27‰, raise carbon concentration two orders of magnitude, and maintain a diamond eclogite composition (McCandless, 1995). Microbial organic carbon is preserved in Proterozoic vent settings

(Loukola-Russkeeniemi et al., 1991), is readily subducted, and can survive subduction without significant fractionation (Shock, 1990).

Hydrothermal fluids in present-day seafloor ridge vent systems effectively circulate through oceanic lithosphere because pressure and temperature conditions exceed the critical endpoint of water, enhancing the ability of water to fracture rock and advect chemical components (Norton, 1984). The Archaean seafloor had more ridges, but shallower ocean depths meant lower pressures, and seawater was prevented from reaching supercritical conditions and forming extensive hydrothermal vent systems. Increased ocean depth in the late Proterozoic enabled supercritical seawater to develop extensive hydrothermal systems (Kasting and Holm, 1992), and a blossoming of microbial vent biota probably followed. Eclogitic diamonds that have been dated are mostly Proterozoic or younger in age. Isotopically light eclogitic diamonds may have formed more readily in Proterozoic and Phanerozoic time because large amounts of organic carbon were not available for subduction before prior to 2.5 Ga ago. The appearance of ^{13}C-depleted eclogitic diamonds may thus be linked with the evolution, and eventual subducton, of the seafloor ridge vent biosphere.

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