GRAPHITE PSEUDOMORPHS AFTER DIAMOND IN THE ECLOGITE-PERIDOTITE MASSIF OF BENI BOUSERA, MOROCCO, AND A REVIEW OF ANOMALOUS DIAMOND OCCURRENCES

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Abnormal and unexplained reported occurrences of diamonds or its pseudomorphs can be categorised as follows (selected references only):

1A. Those occurring in deep-seated lithospheric rocks, including ophiolites and and orogenic ultrabasic rocks that may have suffered subduction and subsequent emplacement as a diapir and/or tectonic wedge, exemplified by Cr spinel dunite/harzburgite/lherzolite e.g. Tibet (Fang Chingson and Bai Wenji, 1981); Koryak Mountains, eastern USSR (Shilo et al., 1981), Kamenushinsk massif, Urals (Sarsädskikh, 1973), Armenia ultramafites (Gevorkyan et al., 1976). Tulameen, British Columbia (Camsell, 1911).

1B. Graphite pseudomorphs after diamond in deep-seated lithospheric rocks of the above category exemplified by eclogites in Beni Bousera (see below).

2A. Sedimentary diamond (placer) deposits closely associated with 1A situation for which a conventional volcanic origin has not been proved e.g. diamond deposits of SE Kalimantan and the occurrences of Thailand; serpentinites of NSW and NW Tasmania (Twelvetrees, 1914), ultrabasics of Alaska, Oregon, California, Carolina, Georgia, Alabama in U.S.A. etc.

2B. Sedimentary diamond deposits of unknown or controversial origin not included in 2A e.g. those of Venezuela; Copeton NSW, Brunette Downs NT, Australia.

2C. Regionally metamorphosed sedimentary diamond deposits, e.g. Birrimian schists of West Africa.

3. Regionally metamorphosed kimberlitic/lamproitic rocks e.g. at Mitzic, Gabon, (Bardet, 1973).

4A. Diamonds in non kimberlitic/lamproitic volcanic rocks representing contamination from diamond bearing gravels and other crustal sources e.g. dolerite at Oakey Creek, Copeton; Icha alkali basalt volcano, Kamchatka (Kaminskii et al. 1981).

4B. Microdiamonds of probable metastable origin in non kimberlitic/lamproitic volcanic rocks.

5. Extra terrestrial origins; meteoritic and shock-impact diamonds, e.g. as postulated for diamonds in Neogene placers of the Dnieper region, Ukraine (Kaminskii et al., 1979).

This paper is concerned with diamonds associated with orogenic ultrabasic massifs of non volcanic origin. They are emplaced close to active plate margins and most recognised examples are Phanerozoic. Host rocks are typically Cr spinel depleted peridotites (dunites, harzburgites) and many are interpreted as ophiolites, i.e. ocean lithosphere. Accompanying high pressure 'indicator' minerals particularly pyrope-rich garnet are not common and indeed it is more usual to find almandine-rich garnet and such minerals as corundum (which however is an indicator in some assumed kimberlite derived diamond alluvials e.g. in Sierra Leone) platinoid metals, rutile, staurolite and florencite (Kaminskii, 1980).

The modern case for orogenic diamonds fostered mainly by Kaminskii and coworkers, although largely based on circumstantial 'alluvial' evidence (group 2A) is most persuasive when related to primary host peridotites of Armenia, Koryak Mountains and Tibet notwithstanding the strong reservations of V.S. Sobolev (Kaminskii, 1980). The discovery of coesite in pyrope-bearing 'alpine schists' (Chopin, 1984) illustrates that crustal rocks can be subducted to great depths, in this case 90km, which after all is only a fraction of the depth of some Benioff zones. A major task is to discover how many deep lithospheric rocks exposed in orogenic or mobile belts have previously been at depths at which coesite (ca. 90 km) or diamond (ca. 150 km) could crystallise, and how these rocks rose quickly to the surface without undue retrogressive effects.

BENI BOUSERA COMPLEX, MOROCCO AND THE PRESENCE OF OCTAHEDRAL GRAPHITE

This layered peridotite and garnet pyroxenite complex and associated thermally metamorphosed gneisses, together with others, notably the Ronda complex, form part of the Betico-Rifean orogenic belt in the western Mediterranean (Kornprobst and Vielzeuf, 1984, and references therein) (Fig. 1).

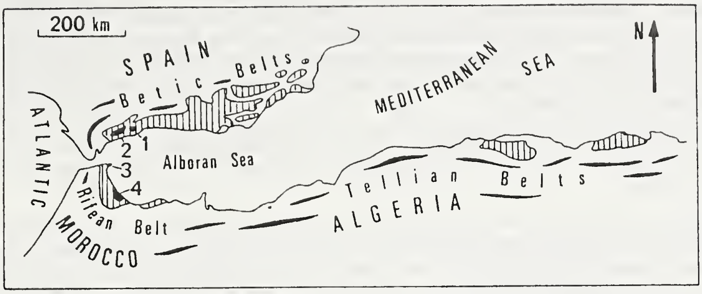

Figure 1. Ultramafic/granulitic associations in the Betico-Rifean belt; southern Spain: 1 - Ronda, 2 - Ojen; Northern Morocco : 3 - Ceuta, 4 - Beni Bousera (Kornprobst and Vielzeuf, 1984).

Kornprobst and Vielzeuf (1984) have described early magmatic parageneses including garnet and corundum pyroxenites, resembling grospydite xenoliths in kimberlites, which crystallised at pressures equivalent to 90 km. Locally, coarse somewhat tectonised banded inequigranular pyroxenites, garnet clinopyroxenites (eclogites) and garnetites contain graphite octahedral pseudomorphs of diamond up to 7mm. across (similar in size to the silicate minerals) and constituting up to 15% of the rock (Slodkevich, 1982). The garnets have spinel bearing coronas; they also occur as inclusions in the graphite. They are mainly py (39-50) alm (32-45) and gross (6-13) with no definite high pressure Si excess yet proved. The clinopyroxenes are omphacites (up to 18% jadeite) with small amounts of Cr_2O_5 (< 0.4 wt%). A small acid resistant residue is currently being examined.

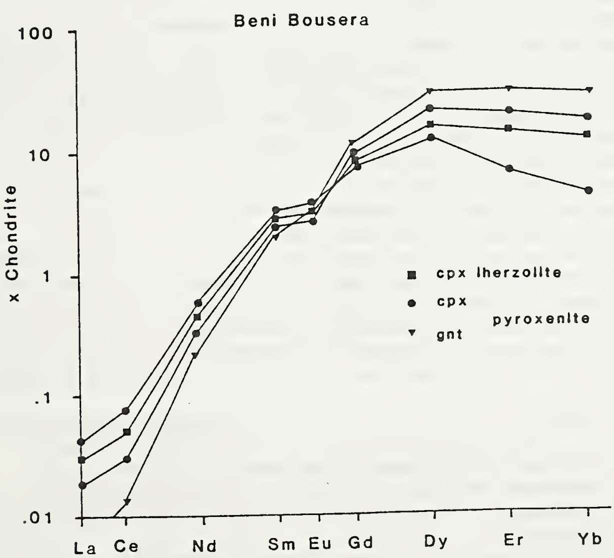

Figure 2. REE patterns of clinopyroxenes and garnets in a spinel lherzolite and graphite-bearing garnet pyroxenite (eclogite) from Beni Bousera.

REE element analysis of cpx and gt, of the graphite bearing pyroxenites and the associated spinel lherzolites, which locally also contain (amorphous) graphite, indicate that both have undergone several partial melting events in the garnet stability field $(Yb)_N = 20$, $(La)_N = 0.03$, $Sm/Nd > 2.0$. (Fig. 2). The relatively unradiogenic $^{143}Nd/^{144}Nd$ ratios of the minerals, 0.5131-0.5132 show that there has been less than 100 Ma since the rocks suffered their last depletion/melting event. Unradiogenic Pb isotope ratios $^{206}Pb/^{204}Pb = 166$ suggest derivation from a long term depleted MORB-like reservoir. However, $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ ratios are comparatively radiogenic (15.2 and 35.7 respectively). These data in conjunction with the radiogenic $^{87}Sr/^{86}Sr$ ratios 0.7045-0.705 imply that some crustal/seawater interaction has occurred in the history of these rocks. $\delta^{13}C$ analyses of the graphite pseudomorphs (Slodkevich,1982) yield high (depleted) values of -19.1 to -22.9 (10 analyses) and -15.5 (1 anal.) suggesting a possible biogenic component.

We interpret the data to indicate the following sequence of events in the context of the Rifean Orogenic Belt and the northward motion of Africa beneath the edge of the European Plate:

Subduction of hydrothermally altered oceanic lithosphere to 150-200 km at which depths (depending on cold slab geotherm considerations) crustal carbon could crystallise as diamond in the deep eclogite facies environment. The degree of depletion during subduction is uncertain.

A heating event of young age and thought to be associated with the Mesozoic (Lias to Senonian) lithospheric extension stage of Kornprobst and Vielzeuf (1984) caused diapiric upwelling of mantle peridotites and eclogite. Segregations of partial melts and crystallisation of diamond took place locally.

The ascent of the diapir (associated with the Betico-Rifean oceanic transform - in the early Tertiary, a compression zone) caused extensive thermal metamorphism of crustal rocks (Kornprobst and Vielzeuf, 1984). The diamonds reverted to graphite but are not significantly deformed.

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