Comparison of Amadeus Basin with Sichuan Basin, southwest China

A project, 'Comparative Studies of Petroleum-bearing Basins in China and Australia', is one of several selected for cooperative research between BMR and the Chinese Ministry of Geology & Mineral Resources under a current Memorandum of Understanding. Within the project a number of sub-projects have been identified, including Gases in Coal-bearing Palaeozoic Basins, Comparative Studies of Palaeozoic Basins, Comparative Studies of Mesozoic and Cenozoic Basins, and The Cambro-Ordovician Boundary.

In April 1988 an Australian delegation comprising Dr Russell Korsch of BMR and Mr John Gorter of John D. Gorter Pty Ltd, Epping, NSW, representing industry, visited the Sichuan Basin in southwest China to compare that basin's structural style, stratigraphy, and hydrocarbon potential with that of the Amadeus Basin in central Australia. The delegation participated in a field trip through the Sichuan Basin, including a visit to the giant Weiyuan gas field, and then travelled through the Yangtze Gorges nearby to examine the regional stratigraphy and structural geology. The delegation visited several Chinese geological institutes and held discussions on the geology, in particular the petroleum potential, of the Sichuan Basin. At each institute lectures were delivered on the geology and petroleum potential of the Amadeus Basin.

For further information, contact Dr Russell Korsch at BMR (Division of Continental Geology) or Mr John Gorter at John D. Gorter Pty Ltd, Petroleum Consultants, PO Box 572, Epping NSW 2121.

Non-volcanic sources of diamond: subducted eclogites and peridotite massifs?

Deep-seated volcanic rocks — kimberlites and more recently lamproites (BMR Research Newsletter, 1, 10; Jaques, Lewis, & Smith, 1986: Geological Survey of Western Australia, Bulletin 132) — are generally considered to be the means by which diamonds are carried from the mantle to the Earth's surface. Recent isotopic dating of diamond indicates that most diamonds are xenocrysts in their volcanic host (BMR Research Newsletter, 6, 15–16) and the presence of diamond rather than graphite at the Earth's surface is due to its metastable preservation by rapid eruption (0.1–10 metres per second) from deep in the mantle.

In contrast to this generally held view there are reports of diamonds in alpine-type peridotite from the USSR (Shilo & others, 1978: Doklady Akademii Nauk SSR, 241, 933–936) and Tibet (Yan & Sun, 1982: Bulletin of the Institute of Geology, Chinese Academy of Geological Sciences, 5, 64) and in metamorphic rocks (Dergachev, 1986: Doklady Akademii Nauk SSSR, 291, 189–190). Other non-kimberlite occurrences of diamond have been described by Kaminsky (1984: Diamondiferous Non-Kimberlitic Rocks, Nedra, Moscow, in Russian). Despite the absence of pyrope garnet and other indicators of high-pressure origin, obducted ophiolites have recently been suggested as the source of certain anomalous occurrences of diamond (Nixon & Bergman 1987: Indisqua, 47, 21–27). More compelling evidence for a non-volcanic origin of certain diamonds has recently come from two sources.
Graphitised diamonds in the Beni Boussera peridotite massif

Octahedral aggregates of graphite up to 12 mm in length inferred to be pseudomorphs after diamonds found in pyroxenite, garnet pyroxenite, and garnetite layers in the Beni Boussera peridotite massif in northern Morocco (Slodkiewicz, 1982; Zapiski Vsesoyuznogo Mineralogicheskogo Obshchestva, 13-33, in Russian). The massif, which forms part of the Palaeozoic Betico-Rifeo orogenic belt, consists mostly of isocrinally folded spinel peridotite with minor pyroxene-rich layers, and was tectonically emplaced from mantle depths of up to 90 km (Korupol & Vleitz, 1984; Developments in Petrology, 11B, 347-359). Recent studies (Pearson & others, 1987; Terra Cognita, 7, 618; Pearson, 1988; Indaqua, 50, 35-39) indicate that not only do the graphite pseudomorphs have forms and surface features comparable with those of diamond but they also contain mineral inclusions similar to eclogitic diamonds, many of which are now believed to have formed from crustal carbon (BMR Research Newsletter, 6, 15-16).

Diamond in high-pressure metamorphic rocks in the Urals

The second source of evidence for transport of diamond in non-volcanic rocks comes from the discovery by Soviet scientists of accessory diamonds included in garnets and zircons from a Caledonian (475 Ma) garnet-biotite gneiss and schist, garnet pyroxenite, and pyroxene-carbonate rock from eclogite-facies rocks in the Kokchetav massif in northern Kazakhstan. This discovery was made at a recent scientific meeting in Novosibirsk (see below) by N.V. Sobolev and co-workers (Sobolev & Shatskii, 1987; Geologiya i Geofizika, 28, 69-72). The diamonds, which have an average size of 12.9 ± 5.8 micrometres and cubo-octahedral forms, are associated with mica, rutile, and zircon, and are commonly associated with graphite. They are believed to have formed in crustal rocks deep in the mantle (at least 120 km) at temperatures of 800-1000°C.

International Symposium, ‘Composition and Processes of Deep-seated Zones of the Continental Lithosphere’

This symposium was held in Novosibirsk, USSR, from 30 May–2 June to commemorate the 80th anniversary of Soviet Academician V.S. Sobolev (1908–1982). Sponsored by the International Lithosphere Program, it was attended by some 120 delegates including 22 from overseas. Prof. H. Green of the University of Tasmania and Dr A.L. Jaques (BMR) attended as invited speakers. In a particularly interesting paper W. Schreyer reviewed studies of the pyrope + coesite-bearing white schists from the Dora Maira massif in the Italian Alps and presented convincing evidence for the transport of crustal rocks to great depths within the Earth (Schreyer, 1988; Episodes, 11, 97-104). The Dora Maira rocks, which crop out over an area of about 200 km2 at depths of 100 km under a low geothermal gradient and then returned rapidly to the Earth’s surface. Schreyer suggested that return transport of deeply subducted continental crust with preservation of such high-temperature minerals is unlikely except under a low geothermal gradient such as in the early phases of collision orogeny.

A major question in diamond research is the relationship between Kimberlite/lamproite magmatism and processes associated with diamond growth in the sub-continental lithosphere (BMR Research Newsletter, 6, 15–16). Several papers presented evidence for a close association between geochemical enrichment (metasomatism) of the deep sub-cratonic lithosphere and alkaline ultrabasic magmatism: this association now seems well established. Large-ion-lithophile-element (LILE)-enriched titanates occluded in diamond (from Yakutia) and K-bearing pyroxene in diamondiferous peridotite (from Argyle) provide mineralogical evidence for geochemical enrichment of the sub-continental lithosphere extending into the diamond stability field. This amplifies the concept of crustal roots extending into the diamond field (150-200 km) first proposed by Boyd & Gurney (1986; Science, 232, 472-476) from studies of xenoliths in kimberlites from southern Africa, where the commercial diamondiferous kimberlites are restricted to the Archean Kaapvaal craton. The lithosphere beneath all cratonic regions appears to have had a complex geochemical history involving early geochemical depletion and later enrichment. The presence of ancient lower-crustal xenoliths in mantle and mantle-derived metasomatic minerals such as Cr-rich LILIE titanates in volcanic rocks indicates development of old, thermally isolated lithosphere potentially favourable for diamond formation. Mantle depletion events associated with the major periods of Precambrian mafic-ultramafic magmatism (such as Archean komatiite magmatism in southern Africa), but metasomatism appears to be a pervasive feature of all cratons and the geochemical enrichment that differentiates them can be related to specific crustal events. However, there is increasing evidence for recycled ancient crustal material in the diamond-forming environment and the source regions of lamproites and micaceous kimberlites.

Alkaline basalts have been proposed to host the diamonds in southeastern Australia (Sutherland & others, 1985; Mineralogical Magazine, 49, 748-751) and elsewhere in the Urals. diamondiferous peridotites have been fuelled by the recent discovery of small diamonds (0.5–2 mm) in Early Cretaceous basaltic diatremes at the western margin of the Syrian-Lebanese rift in western Syria. Two joint Soviet–Syrian papers described the peridotites and their pyroxenes, and the pyroxenes were confirmed in confluence with studies of the xenoliths (eclogite and garnet granulite) and megacrysts (Al-augite, Mg-poor ilmenite, kaersuite, Cr-poor pyrope) that, in common with basaltic rocks elsewhere, the deepest material can be derived by the diatremes appears to have formed at depths no greater than 80 km. From this and the broken and abraded nature of the stones they suggested that the diamonds had another, as yet unknown, primary source.

Implications for diamond exploration

The discoveries of diamond, or, in the case of the Beni Boussera massif, of graphite pseudomorphs after diamonds, in high-grade metamorphic rocks and peridotites indicate that diamonds can form and, in certain favourable circumstances, be tectonically transported to the Earth’s surface in metamorphosed crustal rocks and mantle peridotites. Such rocks must now be considered as possible sources in the course of diamond exploration, and some anomalous alluvial diamonds (e.g. Ural, Copeton?) might have been derived from such sources. A crustal source would explain the unusually heavy delta 13C value (−3.3 to +2.4 per mil) and the peculiar calc-silicate inclusion assemblage of the Copeton diamonds (Sobolev, 1985; University of Western Australia, Geology Department & Extension Service, Publication 8, 215-219). With the exception of the Beni Boussera occurrence where the graphite pseudomorphs are abundant, the very low diamond grade of such occurrences suggests that most are unlikely to constitute primary deposits of economic significance. Nevertheless, recognition that not all diamonds are necessarily derived from kimberlite/lamproite pipes could prevent fruitless exploration for primary volcanic sources of alluvial diamonds shed from non-volcanic sources.

For further information contact Dr Lynton Jaques at BMR (Division of Petrology & Geochemistry).

Use of aeromagnetic flight-line profiles: mapping lithological trends in high-grade gneiss

Recently there has been emphasis on the large amount of geological information that can be interpreted from pixel images of aeromagnetic data. However, many interpreters may not realise that stacked magnetic profiles contain information that cannot be displayed on pixel images. A complete interpretation of aeromagnetic data should consist of combined interpretation of the three presentations: pixel images, contours, and stacked profiles.

A case in point is the high-grade gneiss terrane in the Pinjarra 1 250 000 Sheet area, WA. The pixel map shows many linear and curvilinear features, some at low angles to the flight path. These are interpreted in BMR as cross-cutting faults and dykes. No lithological banding can be inferred. However, the stacked profiles (Fig. 13) show numerous short-wavelength anomalies, many of which can be correlated between adjacent profiles on the basis of their amplitude, characteristic shape, and position relative to large anomalies. They are interpreted as lithological banding, each anomaly being due to a variation in aggregate magnetic along the flight line, not to a single magnetic band. It is difficult to prove this because individual bands cannot be mapped geologically, but the magnetic trends approximate (s.d. = 27°) the mapped foliation trends for the PINJARRA Sheet as a whole. In the Pinjarra Sheet area the data are recorded at 60 km along flight lines 1.5 km apart. The smallest anomalies that can be correlated from line to line have a wavelength of 500 m. In the pixel presentation, data obtained from flight lines are represented on a 400 m grid (a finer grid cannot be used because of the processing difficulty of interpolating between flight lines). It is obviously impossible to determine the existence and shape of a 500 m wavelength anomaly when sampling at 400 m, which is why these anomalies are not apparent on the pixel map.

For further information contact Mr Alan Whittaker or Dr Peter Wellman at BMR (Division of Geophysics).

Fig. 13. Stacked aeromagnetic total-force profiles for part of the PINJARRA Sheet, showing correlation of short-wavelength anomalies.