SHORT COMMUNICATION

Incidence of Diamonds in the Beach Sands of the Kanyakumari Coast, Tamil Nadu

T. K. Rau

Director, Project Diamond, OP: A.P., Geological Survey of India, SR, Hyderabad - 560 068

Email: gsihyd@hyd ap nic in

Abstract: Micro- and macro-diamonds were recovered and studied from the heavy mineral concentrates of beach samples from the southern tip of India. Ranging in size from 0.30 mm x 0 30 mm to 1.50 mm x 2.05 mm, the diamonds are the modified forms of octahedron, dodecahedron and cube and their combinations. Bigger sizes are represented by the broken / cleaved fragments. The diamonds exhibit varied tints of which white, pink and yellow are prominent. This is the second report of diamonds from the beach sands of India and the first of its kind from the Kanyakumari coast with charnockite and khondalite suites of rocks exposed in the hinterland, which shows an important structural grain in the form of the WNW-ESE trending Achankovil shear zone passing close to the present occurrence The possible ultra-high pressure metamorphic and shock origins of these diamonds in SGT are discussed.

Keywords: Diamonds, Beach sands, Kanyakumari coast, Tamil Nadu

Introduction

The Marine Wing of Geological Survey of India has extensively investigated the beach and offshore sediments of both the east and west coast of India for their mineral potential for the last four decades. In the recent past, National Institute of Oceanography and Geological Survey of India have carried out intensive offshore placer exploration. The Geological Survey of India discovered sizeable placer deposits along both the east and west coasts of India during the late eighties and the nineties. Atomic Minerals Directorate for Exploration and Research has estimated a total reserve of 632 MT of placer minerals over a length of 2642 km of beach along the east and west coasts of India, consisting 348 MT of ilmenite, 18 MT of rutile, 21 MT of zircon, 8 MT of monazite, 107 MT of garnet and 130 MT of sillimanite (Ali et al. 2001, 1998; Krishnan, 2000; Mukherjee, 2000).

The modern beaches of southwest coast of India attain significance owing to high concentrations of ilmenite and other heavy minerals (Mallick, 1974; Mallick et al. 1987). Amongst these, extensive placer deposits are located along the Chavara, Manavalakurichi and Midalam beach placer belts with high concentrations of ilmenite, garnet, sillimanite, monazite, zircon and leucoxene in decreasing order of abundance (Unnikrishnan et al. 2002). Systematic sea-bed mapping by surficial sampling followed by preliminary investigation by wide spaced vibrocoring on grid revealed relatively higher accumulation of placer minerals in the near shore area between Inayam (Tamil Nadu) and Vizhinjam (Kerala) with an estimated placer mineral reserve of 4.716 MT in the top 1 m sediments of the seabed over an area of 52.52 sq. km with a break up of 3 055 MT of ilmenite, leucoxene and rutile, 0.185 MT of zircon, 0.143 MT of Monazite, 1.084 MT of sillimanite and 0.249 MT of garnets (Nambiar et al. 2002).

In this scenario, the first ever report of microdiamond (63 - 73 microns) was from the beach placers of the Krishna-Godavari delta along the east coast of Andhra Pradesh (Subrahmanyam et al. 2005). The present report of micro- and macro-diamonds is from the beach sands near Pulimanikulam, located at about 37 km ENE of Kanyakumari, Tamil Nadu, the southern tip of India (Fig.1).

Recovery of Heavy Minerals

Three sand samples, each weighing 2–3 kg, were collected across the beach (08°31'28": 77°47'47" 58H/16) over a distance of about 1 km, covering the wave front, beach dunes and termite mounds. These were washed, dried and jigged in hand-operated Garytz's Jig. The jig concentrates were subjected to heavy liquid separation using bromoform (Sp.gr.1.89). Each of the sample concentrates, weighing around 40-60 g, was examined under binocular microscope.

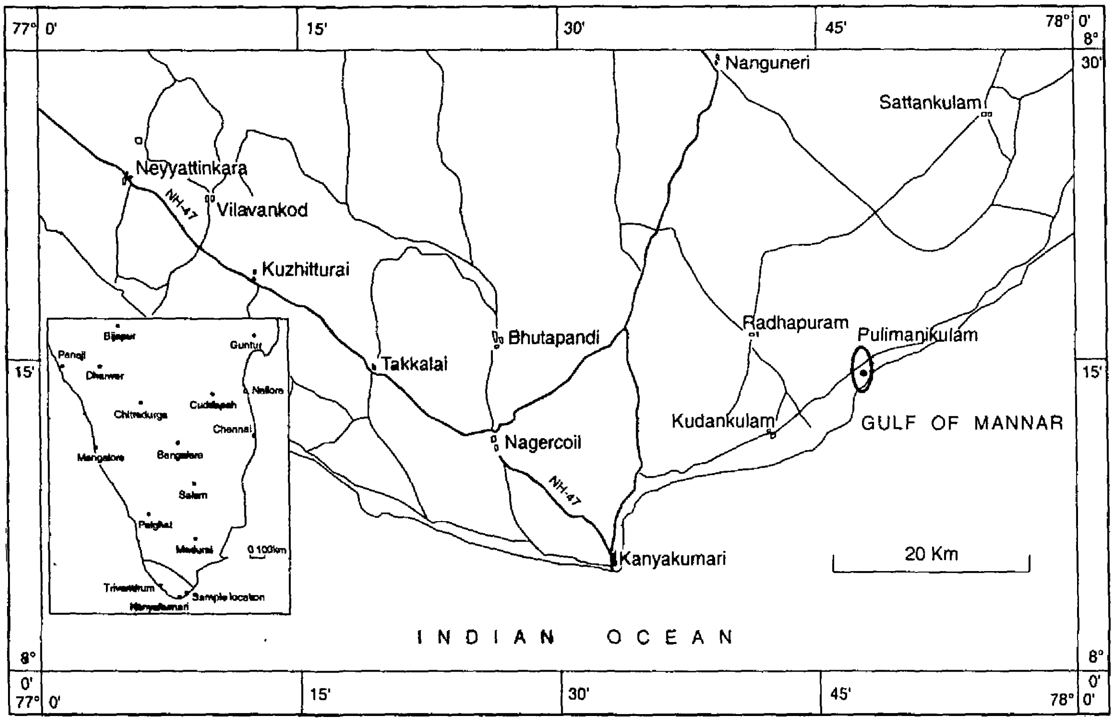

Fig.1. Location map of diamondiferous beach placeres near Pulimanikulam, 37 km ENE of Kanyakumari, Tamil Nadu.

These are rich in pinkish and reddish brown garnets, ilmenite, leucoxene, sillimanite, zircon, diamond, monazite and rutile in that order of decreasing abundance. The heavy concentrates of samples from the surf zone, dunes and termite mounds show predominantly garnets, ilmenite and both respectively.

Recovery of Diamonds

A total number of 207 grains resembling diamond in crystal habit, brilliance and surface morphology were separated from the three samples by picking with a wet brush, and kept immersed in HF (40% GR) in a small Teflon beaker for 48 hours. Subsequently, the grains were kept in a Teflon beaker with a 2:5 ratio solution of 1:1 HF and 1:1 HNO_3 and heated to dryness in a water bath, and again heated with 1:1 HNO_3 to dryness. The acid treatment must have dissolved silicate heavies (garnet, zircon, sillimanite and kyanite) and phosphate heavies (xenotime and monazite), if present amongst these grains. Further, the residual grains were kept immersed in HF (40% GR) for 72 hours. A total of 195 grains sustained the series of acid tests. These did not show even the slightest kind of acid corrosion on their surfaces. In fact, they became more brilliant due to loss of surface coatings.

Study of Diamonds

Weighing 0.335 carats in total, the diamond grains (195 nos.) show a size range of 0.30 mm x 0.35 mm – 1.50 mm x 2.05 mm, falling in the categories of microdiamond (<1.0 mm size) as well as macrodiamond (>1.0 mm size). These grains exhibit high relief due to high R.I. (2.52), strong dispersion, adamantine luster, isotropic nature and surface features like, etch marks (Figs.2.E, F, I), striations (Figs.2E, H), trigons (Figs.2D, F, I) and stepped-growths (Fig.2H) that are characteristic of diamond. These are crystallographically modified forms of cube (Figs.2A, B, F, G), octahedron (Figs.2A, C, F), dodecahedron (Figs.2A, B, D) their combinations (Figs.2A, C, F) and broken/cleaved fragments (Figs.2H). Some crystals show globular (modified dodecahedrons) (Fig.2B) and pear (distorted octahedrons) (Figs.2A, C) shapes. The percentages of size vs. crystal forms of diamonds (195 Nos.) are presented in Table 1. Around 70% of diamonds, which are mainly modified forms of octahedron and dodecahedron, fall within the size range of 0.30 mm x 0.30 mm – 0.60 mm x 0.70 mm. Cleaved and broken fragments falling in the size range of 0.75 mm x 1.00 mm – 1.50 mm x 2.05 mm represent around 18% of diamond population. The diamonds display a wide variety of colours like, white (58%) and black (3%) (Fig.2G) and faint tints of pink (23%), yellow (14%), blue (1%) and brown (1%). They contain isolated tiny jet-black inclusions, which sometimes occur as dusty trains following the crystallographic directions. These inclusions could be titanian magnetite, ilmenite or graphite. A majority of the

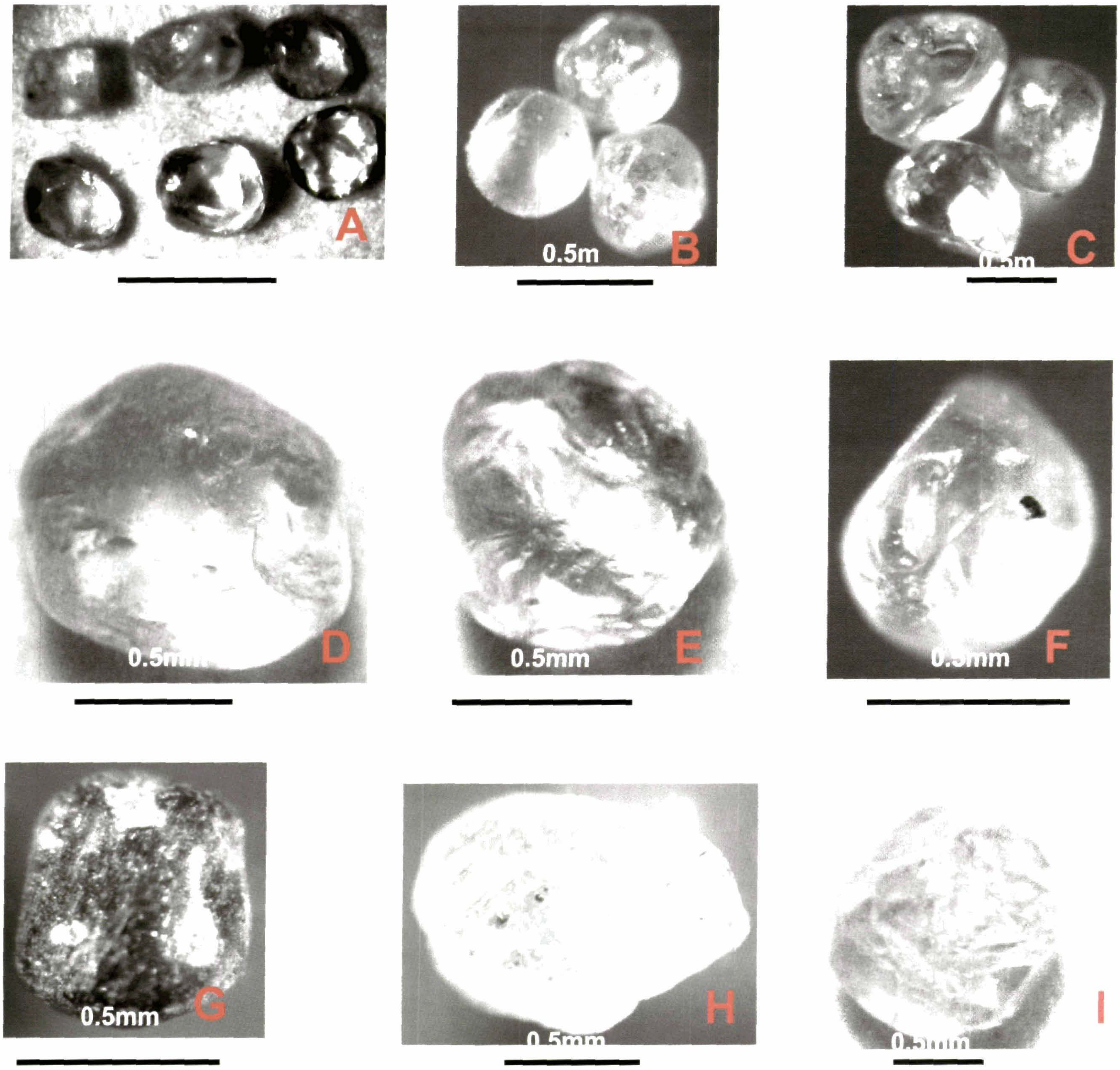

Fig.2. Crystal forms and morphology of diamonds from the beach sands of Kanyakumari. A - Octahedron, dodecahedron and combination forms. B - Modified forms of cube and dodecahedron. C - Combination forms of octahedron and dodecahedron. D - Dodecahedron showing etch marks and trigons. E - Dodecahedron showing etch marks. F - Distorted octahedron showing etch marks and trigons. G - Bort - a modified form of cube. H - Cleaved fragment showing stepped octahedral growth. I - Distorted octahedron showing etch marks.

diamonds show brilliant white and bright yellow glow under the short-wave UV Lamp, whereas a minor population remains inert under both the long- and short-wave UV Lamps.

Discussion

The commonly attributed source for diamond, primary source (kimberlite clan rocks), secondary source (Proterozoic, Eocene and Mio-Pliocene conglomerates) and tertiary source (Quaternary and Recent placers), are not known in the hinterland of the present study area. So far, there are no diamond reports either from the beaches or the offshore regions of the east and west coasts, where Geological Survey of India and National Institute of Oceanography had conducted extensive marine exploratory activities during the last four decades or in the hinterlands in Tamil Nadu and Kerala. The possibility of diamonds getting drifted by the long-shore currents from Andhra

Table 1. Percentages of size *vs* different crystal forms of diamonds

Crystal forms / shapes	Size ranges of diamond grains				
	0 30x0 35 – 0 40x0 55 (mm)	0 50x0 60 – 0 60x0 70 (mm)	0 70x0 80 – 0 75x0 95 (mm)	0 75x1 00 – 0 80x1 10 (mm)	0 40x1 20 – 1 50x2 05 (mm)
Octahedroids (modified forms)	14%	3%	1%	1%	
Pear-shaped (distorted octahedrons)	9%	2%	-	-	
Dodecahedroids (modified forms)	15%	5%	1%	-	
Globular forms (modified dodecahedral forms)	4%	2%			
Cuboids (distorted forms)	7%	1%	4%	1%	1%
Cubo-octahedroids (modified forms)	2%	1%	1%	1%	1%
Fragments	2%	3%	4%	7%	7%

Pradesh coast, where microdiamonds are known to occur (Subrahmanyam et al 2005), to the study area appears to be remote

In fact, the hinterland for the study area forms a part of the Southern Granulite Terrain (SGT), which comprises mainly charnockite and khondalite suites of rocks emplaced with granite and alkali syenite plutons and ultramafic and carbonatite plugs with associated major shears, viz Dharmapuri shear, Moyar-Bhavani shear, Palghat shear and Achankovil shear Alkaline – Carbonatite Complexes (ACCs) of Tamil Nadu, dated around 770 - 800 Ma, are known to contain ultramafic associations, viz dunite, peridotite, pyroxenite and carbonatite at Elagiri, Koratti, Samalpatti, Pakkanadu and Salem (Mazumdar et al 2000) Nevertheless, neither diamonds nor kimberlite clan rocks (KCRs) are reported anywhere in SGT till now It is not known whether the ACCs contain any primary source rocks However, ACCs (770 – 800 Ma) are much younger to the known KCRs (1100 – 1350 Ma) of Andhra Pradesh, Orissa and Madhya Pradesh Though the younger KCRs are not yet known in India, the possibility of discovering them in ACCs cannot be ruled out, as occurrences of even Tertiary KCRs are known elsewhere in the world

The interest of researchers in microdiamonds from kimberlites, lamproites, metamorphic rocks and alluvium deposits has recently been increased (Shatsky et al 1998) Microdiamonds were discovered *in situ* in ultra-high pressure metamorphic (UHPM) rocks (garnet clino-pyroxenites) from the Kokchetav massif, northern Kazakhstan (Sobolev and Shatsky, 1990) These were thought to be (i) diamonds grew stably under UHPM conditions within the equilibrium stability field during a metamorphic event (Sobolev and Shatsky, 1990), (ii) diamonds of metamorphic origin that grew metastably below the diamond equilibrium pressure during a metamorphic event (Dobrzhinetskaya et al , 1994), and (iii) diamonds of mantle origin (KOL), which were deposited in sediments that were metamorphosed (Marakushev et al 1995) Microdiamonds enclosed in garnet, kyanite and zircon were detected in quartzofeldspathic rocks (Gneiss-Eclogite Unit) from the central Saxonian Erzgebirge, Germany (Massonne, 1998) A significant burial of the diamondiferous gneisses to earth depths of at least 130 km suitable for diamond formation occurred (*op cit*) It is interesting to record that the diamonds of metamorphic rocks are dominated by cuboids and cubo-octahedral crystals, whereas those of kimberlites and lamproites by the rounded single-crystals (Shatsky et al 1998)

The occurrences of microdiamonds in UHPM rocks in Kazakhstan and in the quartzofeldspathic rocks in central Saxonian Erzgebirge, Germany encourage the Indian investigators to look for similar occurrences in the granulites of SGT Not to be ignored and equally important is the shock (impact) origin propounded for the diamonds of the Canyon Diablo meteorite (Nininger, 1956) Discovery of impact diamonds in the rocks of a terrestrial meteoritic crater at Popigai astrobleme in Russia enhanced the scope further (Masaitis et al 1972) Now, several similar occurrences of impact diamonds, such as the Ries crater, Germany (Rost et al 1978), Kara and Puchezh-Katunski impact structures of Russia (Ezersky, 1982, Marakushev et al 1993), the Obolon, Il'ntsy, Terny and Zapadny craters of the Ukraine (Gurov et al 1995, Val'ter et al 1992, Val'ter and Er'omenko, 1996) and the Lappajarvi astrobleme in Finland (Masaitis et al 1999), have come to light Besides, redeposited impact diamonds are known to occur in unconsolidated Cenozoic sediments, which were disseminated to form strewn fields around the Popigai crater (Vishnevsky et al 1997) The diamonds in beach placers in the present study area might have been contributed from such terrains, which were never thought to be diamondiferous Thought spreads over a wide arena, but more concerted efforts with a multidisciplinary conceptual approach is needed to unearth the source rocks for the diamond in the study area, besides exploring it further for its diamond potentiality from the economic point of view In view of so many diamond grains (weighing 0 335 carats in total) flashing out of so little a quantity of samples (<10 kg), the beach deserves a detailed probe Though premature at the present stage of investigation, one cannot resist estimating the diamond potential of the beach sands of Pulimanikulam based on the available data, which indicates the amazing figures of 33 50 carats/tonne or 3350 carats/100 tonnes

Acknowledgements The assistance rendered by Shri V Srinivas Choudary and Shri S Ravi, officers of Project Diamond, in laboratory studies including photomicrography and literature consultation is thankfully acknowledged The Director General, Geological Survey of India is thanked for permission to publish the present work Dr S K Bhushan, Deputy Director General, Southern Region and Shri K T Vidyadharan, Deputy Director General, OP Andhra Pradesh, Geological Survey of India are sincerely thanked for providing all the facilities and unstinted encouragement during the course of present work

References

ALI, M A, VISWANATHAN, G and KRISHNAN, S (1998) Beach and inland sand placer deposits of India - Influence of geology, geomorphology and late Quaternary Sea level oscillations in their formation The National Symposium on late Quaternary geology and sea level changes and the Annual Convention of the Geological Society of India, held at Cochin University of Science and Technology, Cochin, India, Abstract Volume, pp 53

DOBRZHINETSKAYA, L F, BRAUN, T V and SHESHKEL, G G and PODKUIKO, Y A (1994) Geology and structure of diamond-bearing rocks of the Kokchetav massif (Kazakhstan) Tectonophysics, v 233, pp 293-313

EZERSKY, V A (1982) The shock metamorphosed carbon matter in impactites Meteoritika, v 41, pp 134-140 (*in Russian*)

GIOVANNI PRATESI, ALESSANDRO LO GIUDICE, SERGEI VISHNEVSKY, CLAYDIO MANFREDOTTI and CURZIO CIPRIANI (2003) Cathodoluminescence investigations on the Popigai, Ries, and Lappajarvi impact diamonds American Mineralogist, v 88, pp 1778-1787

GUROV, E P, GUROVA, E P and RAKITSKAYA, R B (1995) Impact diamonds in the craters of the Ukrainian Shield Meteoritics, v 31, pp 515-516

KRISHNAN, S (2000) Presidential address *In* G V Rajamanickam (Ed), Hand Book of Placer Mineral Deposits, New Academic Publishers, Delhi, pp 27-30

MALLICK, T K (1974) Heavy mineral placers in the beaches and offshore areas - Their nature, origin, economic potential and exploration Indian Minerals, v 28(31), pp 39-46

MALLICK, T K, VASUDEVAN, V, ABY VERGHESSE, P and TERRY MACHADO (1987) The black sand placer deposits of Kerala beach, southwest India Marine Geology, v 77, pp 129-150

MARAKUSHEV, A A, PERTSEV, N N, ZOTOV, I A, PANCYAKCH, N A and CHERENKOVA, A P (1995) Some petrological aspects of diamond genesis Geology of Ore Deposits v 37, pp 105-121

MARAKUSHEV, A A, BOGATYREV, O S, FENOGENOV, A D, PANEYAKH, N A and FEDOSOVA, S P (1993) Impactogenesis and volcanism Petrology, v 1, pp 571-595 (*in Russian*)

MASAITIS, V I, FUTERGENDLER, S I and GNEVYSHEV, M A (1972) The diamonds in the impactites of the Popigai meteoritic crater Zapski Vsesouzuogo Mineralogicheskogo Obstchestva, v 101, pp 108-113

MASAITIS, V I, SHAFRANOVSKY, G I, FEDONOVA, I G, KOIVISTO, M and KORHONEN, J V (1998) Lappajärvi Astrobleme The first find of impact diamonds on the Fennoscandian Shield Lunar and Planetary Science Conference, 29 Abstract No 1171

MASSONNE, H J (1998) A new occurrence of microdiamonds in Quartzofeldspathic rocks of the Saxonian Erzgebirge, Germany, and their metamorphic evolution VII IKC, University Of Cape Town, South Africa, V II, P (Nixon Ed), pp 533-539

MAZUMDAR, S K, KAMESWARA RAO, T and NATHAN, N P (2000) Alkaline complexes of southern and eastern India – An over view Geol Surv India, Spl Pub No 55, pp 101-134

MUKHERJEE, T K (2000) Inaugural Address – Exploitation of heavy mineral resources in India *In* G V Rajamanickam (Ed), Hand Book of Placer Mineral Deposits, New Academic Publishers, Delhi, pp 9-26

NAMBIAR, A R, ABDULLA, N M, DINESH, A C, GANGADHARAN, A V, JAYAKUMAR, R, JAYAPRAKASH, C, KANNAN, S, RAO, M K, CHARLU, T K, KUMARAN, K, RAMACHANDRAN, K V, PAI, P R, RAHOTHAMAN, V K, ADIGA, K S, UNNIKRISHNAN, E, NAIR, E V, VENKATARAMANA, P and ZAHEER, B (2002) Prospecting for offshore placer deposits in the area between Inayam (Tamil Nadu) and Vizhinjam (Kerala) in southwest coast of India Four Decades of Marine Sciences in India – A Retrospect, National Seminar Organized in connection with 150th Year Celebrations of Geological Survey of India, March, 2001, pp 146-155

NININGER, H H (1956) Arizona's meteorite crater Its past, present and future, 232p World Press Inc, Denver, Colorado

ROST, R, DOLGOV, YU, A and VISHNEVSKY, S A (1978) Gas inclusions and high pressure polymorphs of carbon in the impact glasses of the Reiss crater Doklady Akademii Nauk SSSR, v 241, pp 695-698 (*in Russian*)

SHATSKY, V S, ZEDGENIZOV, D A, YEFIMOVA, E S, RYLOV, G M, De Corte, K and Sobolev, N V (1998) A comparison of morphology and physical properties of microdiamonds from the mantle and crustal environments *In* Nixon (Ed), VII IKC, University of Cape Town, South Africa, v II, P, pp 757-763

Sobolov, N V and Shatsky, V S (1990) Diamond inclusions in garnets from metamorphic rocks a new environment for diamond formation Nature, v 343, pp 742-746

Subrahmanyam, A V, Anil Kumar, V, Desapati, T, Deshmukh, R D and Viswnathan, G (2005) Discovery of micro-diamonds in beach placers of the east coast, Andhra Pradesh, India Curr Sci, v 88, No 8, pp 1227-1228

Unnikrishnan, E, Nambiar, A R and Vidhyadharan, K T (2002) Textural and mineralogical variation across a heavy mineral rich beach at Midalam, southwest coast of India Four Decades of Marine Sciences in India – A Retrospect, National Seminar organized in connection with 150th Year Celebrations of Geological Survey of India, March 2001, Geol Surv India, Spl Pub No 74, pp 165-171

Val'ter, A A and Er'omenko, G K (1996) Carbon minerals in rocks of astroblemes, Meteoritics and Planetary Science 31, Supplement, p A144

Val'ter, A A Er'menko, G K, Kvasnitsa, V N and Polkanov, Yu A (1992) The shock metamorphic minerals of carbon, 172p Naukova Dumka Press, Kiev (*in Russian*)

Vishnevsky, S A, Afanas'ev, V P, Argumov, K P and Pal'chik, N A (1997) Impact diamonds their features, origin and significance Transactions of the UIGGM SO RAN, Issue No 385, Novosibirsk Siberian Branch of Russian Academy of Sciences Press, 1997, 110p (*in Russian & English*)

(Received 19 September 2005, Revised form accepted 15 October 2005)