Discovery of micro-diamonds in beach sands of the Nagapattinam and Vedaranniyam beaches, southern east coast of India

Diamonds are known for their brilliant lustre and longevity owing to their hard nature among all the minerals, by virtue of strong covalent bonding. They are 3D crystalline carbon that may be transparent and always isotropic between crossed nocols, or opaque and have a tensile strength up to 60 GPa[1].

Increased industrial use of micro- (>0.1 mm diameter) as well as macro-diamonds or simply diamonds (<1.0 mm)[2] has made all the deposits economically viable, increasing the scope of possible resources, including beach sands.

Beaches seem to portray annual sum of all the products derived from the catchments of nearby rivers, coastal belt and continental region, which also include shelf detritus grains derived from the coastal rocks with concentration of heavy minerals.

Reports of cuboid and cubo-octahedral micro-diamond from Recent and palaeo-placer deposits (Krishna–Godavari delta, Kanniyakumari and other beaches) of the east coast of India[1–4], derived from the metamorphic rocks have enhanced the prospects of such exploration.

The present investigation reports results of a regional study on texture, composition and distribution of heavy minerals from 16 sandy beaches along the entire east coast of India covering a coastal stretch of around 2500 km from Puri to Kanniyakumari (M. K. Purohit, unpublished). The study has yielded 16 isotropic grains from Nagapattinam (10°45′ lat., 79°51′ long.) and 13 from Vedaranniyam. (10°24′ lat., 79°52′ long.; Figure 1), showing high relief, high reflectivity and morphology that differ from optical characteristics of other heavy minerals. The whole-grain study using stereo-binocular microscope and mounted-grain study using petrological microscope revealed that they were micro-diamonds.

Nine samples, 500 g each, were collected on grid pattern (three across and three along the beaches) at a distance of 2 m from each other across the beach and 5 m along the beach at each station. The samples were dried and mixed thoroughly to obtain a 20 g representative fraction from all the stations by coning-and-quartering. The samples were then wet-sieved to wash the dissoluble substances in 230 ASTM sieves (phosphor-bronze) with 0.063 mesh opening until clear waters started coming. The total outflow was kept under 1000 ml volume. The filtered fraction was wet-sieved through a sieve set (30, 60, 100, 150, 200 μm and Pan) to separate the mesh fractions of sediments for quantitative and qualitative analyses. The fractions were then dried again in a hot aerated oven on 50°C and weighed separately to obtain their weight percentages.

The cleaned fractions (+30, +60, +100, +150, +200 mesh) were separated for heavy minerals like ilmenite, rutile, zircon, garnet, sillimanite and monazite using bromoform (2.85 specific gravity) as a separating medium and centrifuged for 10 min. All the grains showing brilliant adamantine lustre were hand-picked and identified as micro-diamonds using a polarizing microscope in a methylene iodide medium (R.I.:1.8) for morphological and optical characters (M. K. Purohit, unpublished). Samples from only two stations, viz. Vedaranniyam and Nagapattinam yielded cuboid and cubo-octahedral diamonds.

Diamond belongs to the isometric system and may be differentiated from other non-isotropic heavy minerals owing to isotropism, high relief, distinct shape, form and morphology (M. K. Purohit, unpublished). They reflect more amount of light from their surface compared to other heavy minerals, and their form is mostly octahedron. Diamonds are recognized by physical properties like hardness, specific gravity, fluorescence, thermal conductivity, transparency to X-rays, etc.[5,6]. The morphological and optical characteristics of diamonds are also seen in micro-diamonds with conchoidal fractures and adamantine lustre.

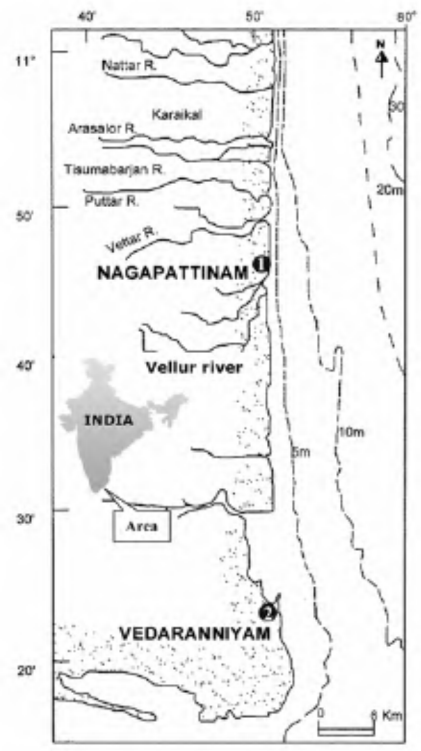

Figure 1. Location of sampling points (1) Nagapattinam and (2) Vedaranniyam beaches on the east coast of India.

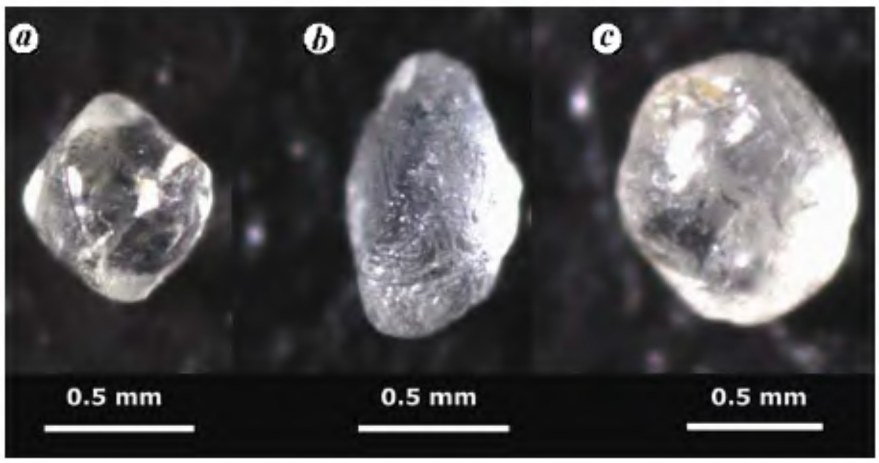

Figure 2. Micro-diamonds from Nagapattinam (***a***, ***b***) and Vedaranniyam (***c***) beach sands.

Table 1. Granulometry at Nagapattinam and Vedaranniyam beaches on the east coast of India

	Wt %									
	30		60		100		150		200	
Station no.	Phi	Wt %	Phi	Wt %	Phi	Wt %	Phi	Wt %	Phi	Wt %
1	0.75	0.29	2.0	7.84	2.75	12.58	3.32	63.67	3.75	12.61
2	0.75	0.12	2.0	1.48	2.75	35.89	3.32	54.05	3.75	0.499

1, Nagapattinam; 2, Vedaranniyam.

Table 2. Distribution of heavy minerals at Nagapattinam and Vedaranniyam beaches

	Numbers/20 g													
Station no.	zi	gt	mon	tour	epi	hb	ru	ky	st	and	sill	ana	bio	diam
1	119026	18571	537	2875	291	773	661	583	1889	344	375	–	145	16
2	66977	17339	16559	8404	290	676	548	395	890	375	289	15	102	10

1, Nagapattinam; 2, Vedaranniyam.
Heavy minerals – zi, Zircon; gt, Garnet; mon, Monazite; tour, Tourmaline; epi, Epidote; hb, Horneblend; ky, Kynaite; st, Staurolite; ru, Rutile; and, Andalucite; sill, Sillimanite; ana, Anatase; bio, Biotite; diam, Diamonds (micro-diamonds).

In Nagapattinam sand samples (Tables 1 and 2), the average size of micro-diamonds was 0.25 mm (or more). They were recovered from +60 μm mesh (2 phi) fraction as colourless to pale yellow detritus without inclusions (Figure 2). Whereas in the Vedaranniyam samples they showed an average size of 0.5 mm and were recovered from +100 μm mesh (2.75 phi) fraction as colourless or pinkish-yellow, cubic or dodecahedron. Those shown in Figure 2 *a* and *c* are slightly to moderately etched and the one shown on Figure 2 *b* is cleaved.

The size of the micro-diamonds encountered at Nagapattinam and Vedaranniyam beach sands points to a long distance of transport. The cuboid and cubo-octahedral shape indicate their possible release from metamorphic rocks while globular (modified dodecahedral) grains indicate their release from a kimberlite/lamporite source also[2,3]. Possibility of their occurrences, however, at the two stations in coarser sediments may not be ruled out. The XRD of the two samples substantiates the presence of micro-diamonds (peak values 2.01, 1.26 and 1.08; M. K. Purohit, unpublished).

Beach samples of Nagapattinam and Vedaranniyam also indicate indirect evidences of kimberlite owing to the presence of kimberlite indicating minerals[7] like uvarovite which occurs in both the beaches, while Cr-spinel occurs only in the latter.

The present report, therefore, enhances the prospects of diamond exploration in the coastal zones along the east coast of India.

ADDENDUM: The possibility of some of the micro-diamonds being meteoritic in origin may not be ruled out as they may be released from primitive meteorites[8,9]. Such micro-diamonds show elemental and isotopic characteristics that depend on the host meteorite type and differ from kimberlite-derived micro-diamonds in their N content and low-temperature Xe-component (Xe-P3)[10,11].

The N content and Xe-P3 will be worked out and published in future.

1. Telling, R. H., Pickard, C. J., Payne, M. C. and Field, J. E., *Phys. Rev. Lett.*, 2000, **84**, 5160–5163.
2. Rau, T. K., *J. Geol. Soc. India*, 2006, **67**, 11–15.
3. Shatsky, V. S., Zedgenizov, D. A., Yefimova, E. S., Relov, G. M., De Corte, K. and Sobolev, N. V., In *A Comparison of Morphology and Physical Properties of Micro-diamonds from the Mantle and Crustal Environments* (ed. Nixon), VII IKC, University of Cape Town, South Africa, 1998, pp. 757–763.
4. Subrahmanyam, A. V., Kumar, V. K., Desapati, T., Deshmukh, R. D. and Viswanathan, G., *Curr. Sci.*, 2005, **88**, 1227–1228.
5. Babu, T. M., *Diamond in India*, Geological Society of India, Bangalore, 1998, p. 314.
6. Sudha, P., *Geol. Surv. India, Misc. Publ. No. 19*, 1971, 134–140.
7. Ravi, S. and Satyanarayana, S. V., *J. Geol. Soc. India*, 2007, **70**, 689–692.
8. Huss, G. R. and Lewis, R. S., *Meteoritics*, 1991, **26**, 348.
9. Allamandola, L. J., Sandford, S. A., Tielens, A. G. G. M. and Herbst, T. M., *Science*, 1993, **260**, 64–66.
10. Murty, S. V. S., Sahijpal, S., Fisenko, A. V., Semjonova, L. P., Shukolyukov, Y. A. and Goswami, J. N., *Meteoritics*, 1993, **28**, 405.
11. Radhakrishna, B. P., *J. Geol. Soc. India*, 2008, **72**, 709.

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