

Diamondiferous Kimberlite-Clan Magmatism of Central India: Location, Emplacement Type and Period of the Majhgawan, Bunder and Behradih Diamond Fields (Bundelkhand and Bastar Cratons), with a Comparative Analysis and Future Prospects

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Abstract:

A Central India hosts the country's three most important primary diamond fields, distributed across two Archaean cratons: the Majhgawan-Hinota diatremes (Panna district) and the Bunder (Saptarshi) lamproite cluster (Chhatarpur district) on the Bundelkhand Craton, and the Behradih pipe of the Mainpur Kimberlite Field (Gariaband district, Chhattisgarh) on the Bastar Craton. This paper reviews their locations, geological settings, emplacement types and emplacement periods, and develops a three-way comparative analysis followed by an assessment of future prospects. The Bundelkhand fields are Mesoproterozoic: phlogopite Ar-Ar and Rb-Sr ages of $\sim 1073.5 \pm 13.7$ Ma (Majhgawan) and $1079 \pm 6 / 1064 \pm 15$ Ma (Atri pipe, Bunder) record a single ~ 1.1 Ga event, coeval with Dharwar kimberlites and the Argyle lamproite, in which anomalous, transitional kimberlite-orangeite-lamproite magmas ('majhgawanite'-type, metasomatised lithospheric mantle group) pierced Kaimur Group platformal cover on the southern craton margin. In sharp contrast, the diamondiferous Behradih pipe is an end-Cretaceous (~ 65 Ma) orangeite (Group II kimberlite) - the first well-documented orangeite occurrence outside the Kaapvaal Craton - emplaced into Archaean granitoids at the core of the Bastar Craton synchronously with Deccan flood-basalt volcanism, implying plume-lithosphere interaction. The comparison shows that diamondiferous magmatism in central India is polycyclic (~ 1.1 Ga and ~ 65 Ma), petrologically hybrid rather than archetypal Group I kimberlite, and controlled in both cratons by thick, anciently metasomatised lithospheric keels. Future prospectivity is high: the Vindhyan-concealed Bundelkhand margin, the undeveloped ~ 27.4 Mct Atri resource, the untested pipes and alluvial trains of the Mainpur field, and the possibility of further end-Cretaceous pipes concealed beneath Deccan Traps and basin cover together define one of the more underexplored diamond provinces on any Archaean craton.

Key Word: Bundelkhand Craton; Bastar Craton; Majhgawan; Bunder; Behradih; Mainpur Kimberlite Field; orangeite; lamproite; diamond; Deccan Traps; future prospects

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I. Introduction

India was the world's first and, for two millennia, only source of diamonds, yet nearly all historical production came from secondary (alluvial and conglomerate-hosted) deposits. The primary sources have emerged only over the past century: the Majhgawan diatreme near Panna (mined mechanically since the mid-twentieth century), the Bunder lamproite cluster discovered by Rio Tinto in 2004, and the Mainpur Kimberlite Field of Chhattisgarh, whose largest member (Behradih pipe) was confirmed as significantly diamondiferous by drilling and reconnaissance diamond studies in the 1990s-2000s.

These three fields sit on two different cratonic blocks (Figs. 1, 2): Majhgawan and Bunder on the Bundelkhand Craton, and Behradih on the Bastar Craton, the two being separated by the Central Indian Tectonic Zone (CITZ). They also belong to two entirely different magmatic epochs, Mesoproterozoic (~ 1.1 Ga) and end-Cretaceous (~ 65 Ma). This paper (i) documents the location and setting of each field; (ii) synthesises their emplacement types (rock classification and eruptive style) and emplacement periods (geochronology); (iii) presents a systematic three-way comparative analysis; and (iv) evaluates the future prospects of kimberlite-clan exploration in central India.

Regional Geological Setting

The Bundelkhand Craton

The Bundelkhand Craton is a semicircular Archaean terrane (~26,000-29,000 km²) in Uttar Pradesh and Madhya Pradesh, dominated by the Bundelkhand Granitoid Complex (TTG gneisses and ~2.5 Ga potassic granites) with greenstone enclaves and crustal components as old as ~3.5 Ga. It is bounded by the Great Boundary Fault (NW), the Son-Narmada lineament and CITZ (S), and Indo-Gangetic alluvium (N). Along its southern flank the basement is overlain by the Meso- to Neoproterozoic Vindhyan Supergroup; both the Majhgawan-Hinota and Bunder pipes were emplaced through the ~1.1 Ga Kaimur Group of this platformal cover - a classic 'archon' configuration in the sense of Clifford's Rule.

The Bastar Craton

The Bastar (Bhandara) Craton of Chhattisgarh, eastern Maharashtra and adjoining states is among the oldest nuclei of the Indian shield, containing Eoarchaean (3.5-3.6 Ga) granitoid crust, supracrustal belts (Sukma, Bengpal, Sonakhan), and extensive ~2.5-2.3 Ga granites. Proterozoic platformal basins (Chhattisgarh, Indravati, Khariar/Pairi) rest on the basement, and the craton is bounded by the CITZ to the north, the Eastern Ghats belt to the southeast, the Godavari rift to the southwest, and is fringed by Deccan Traps to the west. Two kimberlite-clan fields are known: the diamondiferous Mainpur Kimberlite Field (MKF) near the Bastar craton's core in Gariaband district (Behradih, Kodomali, Payalikhanda, Jangra, Kosambura and related intrusions), and the essentially barren crater-facies Tokapal-Bejripadar system in Bastar district farther south.

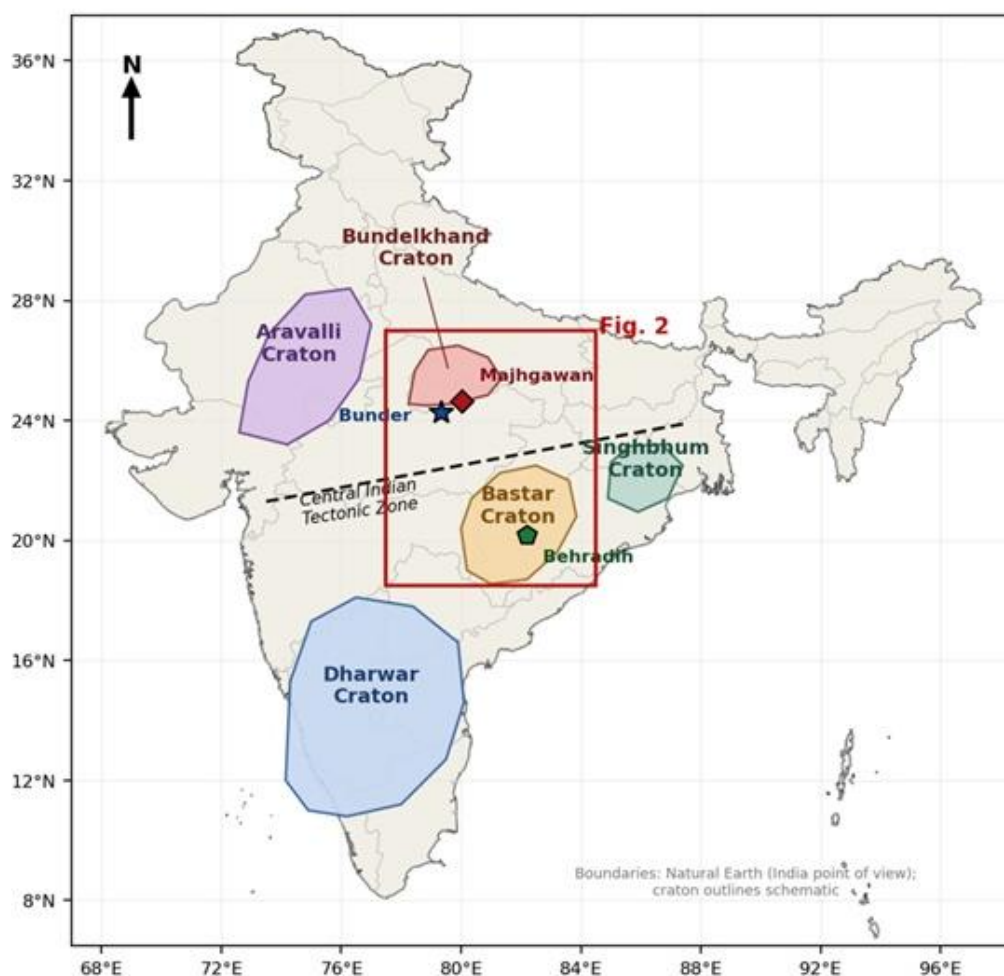


Fig. 1. Archaean cratonic framework of Peninsular India (Aravalli, Bundelkhand, Singhbhum, Bastar and Dharwar cratons) showing the Majhgawan, Bunder and Behradih diamond fields and the study area of Fig. 2 (red box). Country and state boundaries from Natural Earth; craton outlines schematic.

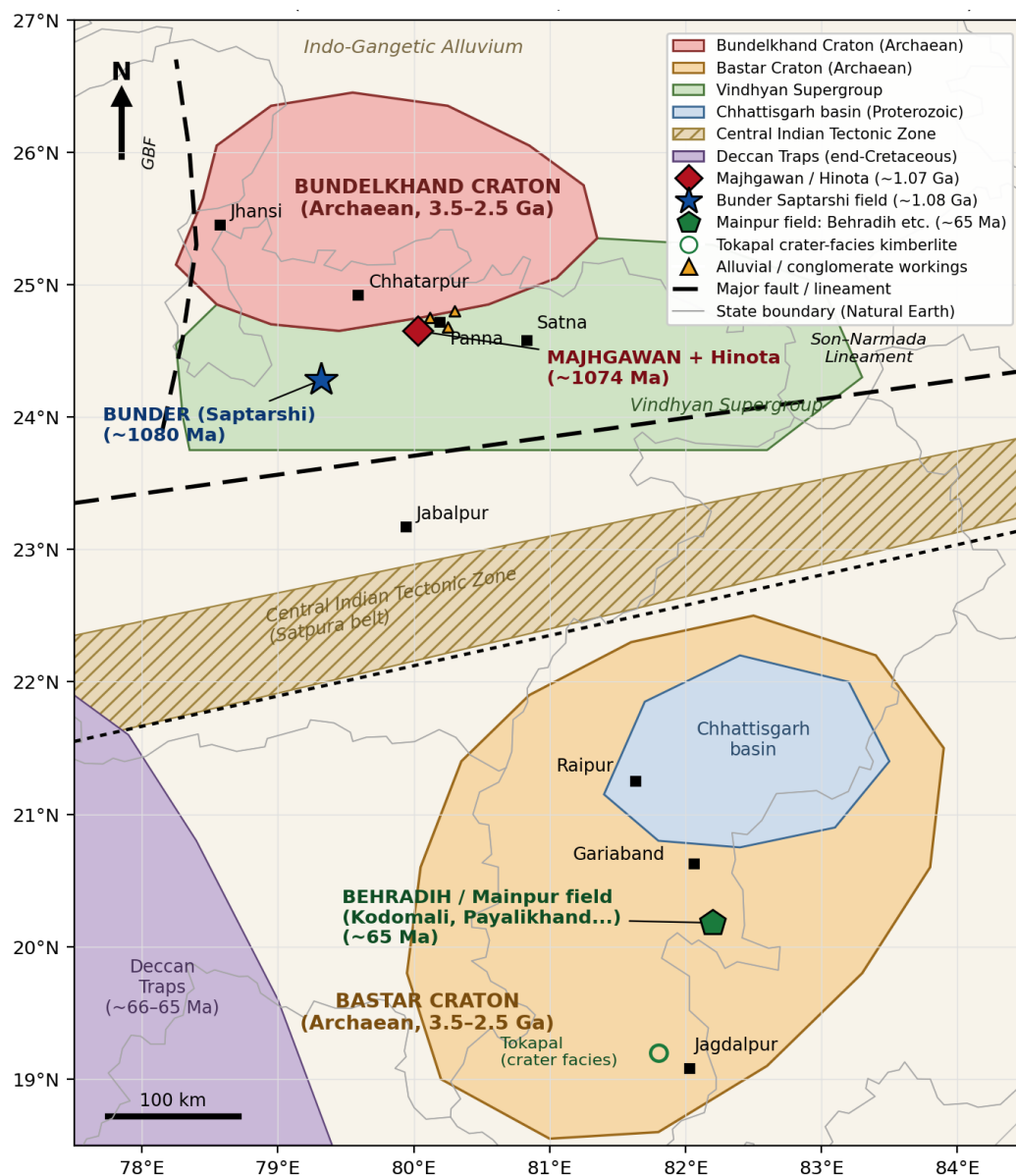


Fig. 2. Geological sketch of the study area showing the Bundelkhand and Bastar cratons, the Vindhyan and Chhattisgarh cover basins, the Central Indian Tectonic Zone, Deccan Traps, and the Majhgawan (~1074 Ma), Bunder (~1080 Ma) and Behradih/Mainpur (~65 Ma) diamond fields. Unit outlines schematic; state boundaries from Natural Earth.

II. Material And Methods

This synthesis draws on published petrological, geochemical and geochronological studies of the three fields, Geological Survey of India and Directorate of Geology & Mining (Chhattisgarh) records, exploration-company publications, and review volumes on Indian diamond geology. Locations, dimensions, grades and ages are compiled from these sources; Figs. 1 and 2 were compiled for this paper using Natural Earth country and state boundaries, with schematic geological outlines after published craton maps.

III. Result

The Majhgawan Diamond Field, Panna (Bundelkhand Craton)

The Majhgawan pipe (~24°39'N, 80°02'E), with its smaller satellite Hinota, lies about 20 km southwest of Panna town, intruding flat-lying Kaimur Group sandstones above ~2.5 Ga Bundelkhand granite. It is a carrot-shaped diatreme, ~500 × 370 m at surface, preserved at a shallow erosion level so that diatreme-facies volcanoclastic rocks (lapilli tuffs) dominate. Petrographic re-examination showed the rock to be an olivine lamproite lapilli tuff rather than an archetypal kimberlite, and subsequent mineral-chemical and isotopic work

established a transitional kimberlite-orangeite-lamproite character, prompting the informal name 'majhgawanite'. Radiometric ages (Ar-Ar phlogopite 1073.5 ± 13.7 Ma; Rb-Sr ~ 1067 and 1044 ± 15 Ma) fix emplacement in the Mesoproterozoic at ~ 1.07 Ga. Majhgawan sustains India's only mechanised diamond mine (NMDC), historically producing roughly ten to eighty-odd thousand carats per year at ~ 8 -13 cpht, and has fed the famous Panna alluvial workings since at least the 13th century.

The Bunder Diamond Field, Chhatarpur (Bundelkhand Craton)

The Bunder project near Buxwaha (~ 80 km SSW of Majhgawan) comprises the seven-pipe Saptarshi cluster discovered by Rio Tinto in 2004, of which the Atri pipe (South and North lobes) is the principal diamondiferous body. The steep-sided pipes were emplaced through ~ 1.1 Ga Kaimur Group platformal sediments and are infilled by multiple phases of pyroclastic material with variably coherent margins; Atri North post-dates Atri South. Classification within the kimberlite-orangeite-lamproite scheme is not possible: mineral chemistry has both lamproite and orangeite affinities while Sr-Nd isotopes ($^{87}\text{Sr}/^{86}\text{Sr}$ 0.7038-0.7048; $\epsilon\text{Nd} +1.6$ to -1.8) resemble archetypal kimberlites, so the pipes - like Majhgawan-Hinota - are assigned to a metasomatised lithospheric mantle magma group, though they are commonly termed the Bunder lamproites. Rb-Sr phlogopite ages of 1079 ± 6 Ma and 1064 ± 15 Ma are indistinguishable from Majhgawan. The Atri pipe hosts an inferred resource of ~ 37 Mt containing ~ 27.4 million carats (~ 0.7 ct/t), with white-to-brown, commonly plastically deformed diamonds resembling Majhgawan and Argyle stones. Rio Tinto relinquished the project in 2017; it was auctioned to Essel Mining & Industries Ltd (Aditya Birla Group) in 2019, and development currently awaits environmental and forest clearances at Buxwaha.

The Behradih Pipe and the Mainpur Kimberlite Field, Gariaband (Bastar Craton)

Location and geological setting

The Mainpur Kimberlite Field lies in the Mainpur-Behradih area of Gariaband district (formerly part of Raipur district), southern Chhattisgarh ($\sim 20^\circ 12' \text{N}$, $82^\circ 12' \text{E}$), at the core of the Bastar Craton and close to the southeastern margin of the Chhattisgarh basin. Six intrusions are known - Behradih, Kodomali, Payalikhand, Jangra, Kosambura and associated bodies - emplaced into Archaean Bastar granitoids. Behradih, with a surface expression of $\sim 300 \times 160$ m, is the largest and best-studied diamondiferous member; regional alluvial diamonds in the Mahanadi-Pairi drainage have long pointed to primary sources in this terrain. The crater-facies Tokapal system, ~ 120 km to the south in Bastar district, belongs to the same clan but is essentially barren.

6.2 Emplacement type

Behradih is a diatreme-facies, volatile-driven explosive pipe consisting of pelletal lapilli and olivine-phlogopite macrocrysts in a groundmass of clinopyroxene, chrome spinel, apatite, Fe-rich perovskite, zircon, titanite, rutile and calcite, pervasively altered to serpentine-talc-carbonate assemblages. Mineralogical, geochemical and Sr-Nd isotopic studies identify the pipe as an orangeite (formerly Group II kimberlite) - establishing the first well-documented occurrence of orangeite outside the Kaapvaal Craton of southern Africa. The nearby Kodomali pipe has alternatively been described as orangeite and as 'lamproite-like', but its isotopic and mineralogical similarity to Behradih supports widespread end-Cretaceous orangeite magmatism in the Bastar Craton. The presence of macrodiamonds requires magma sourcing from depths exceeding ~ 140 km, within the diamond stability field of a thick lithospheric keel.

Emplacement period

Combined $^{40}\text{Ar}/^{39}\text{Ar}$ (whole-rock) and U-Pb (perovskite) dating places Behradih emplacement at ~ 65 Ma, with Kodomali at ~ 62 Ma - an end-Cretaceous to earliest Palaeocene (K-Pg boundary) event synchronous with the main phase of Deccan flood-basalt eruption. An earlier Ar-Ar result suggesting a Pan-African (491 ± 11 Ma) age for Kodomali has been superseded by this work. The synchronicity with the Deccan event, together with the field's intracratonic position away from major rifts, is interpreted as evidence of Réunion-plume-lithosphere interaction beneath the Bastar Craton.

Diamond content and status

Reconnaissance studies recovered 34 macrodiamonds (0.6-2.2 mm) and 86 microdiamonds from Behradih drillcore; the stones are mostly colourless with minor light brown and pale yellow populations, show significant resorption, and contain 358-950 at. ppm structurally bound nitrogen. Prospecting by the Directorate of Geology & Mining and others (including bulk-sample programmes in the Behradih-Kodomali area) confirms genuine diamond potential, but no compliant resource or mine has yet been established, and the field remains at an advanced prospect stage.

Emplacement Type and Period: A Two-Craton Synthesis

Central Indian diamondiferous magmatism is polycyclic. The first cycle, at ~1.10-1.06 Ga (Mesoproterozoic, Stenian), produced the Majhgawan-Hinota and Bunder fields on the reactivated southern margin of the Bundelkhand Craton, coincident with a global pulse that includes the Wajrakarur-Narayanpet kimberlites of the Eastern Dharwar Craton, the Argyle lamproite (~1.18 Ga) and the Premier kimberlite (~1.15 Ga), and is widely linked to stresses accompanying Rodinia assembly. The second cycle, at ~65-62 Ma (end-Cretaceous), produced the Mainpur orangeites at the core of the Bastar Craton, synchronous with Deccan volcanism and attributed to Réunion-plume impingement on thick cratonic lithosphere. In both cycles the magmas are not archetypal Group I kimberlites: the Bundelkhand pipes are transitional 'majhgawanite'-type rocks of the metasomatised-lithospheric-mantle group, and the Bastar pipes are orangeites. In both cratons, emplacement style is the same - small-volume, volatile-rich explosive diatreme volcanism - and the essential precondition is identical: an old, thick, anciently metasomatised lithospheric keel extending into the diamond stability field.

Comparative Analysis of the Majhgawan, Bunder and Behradih Fields

Table 1 summarises the geological and economic attributes of the three fields. Several first-order patterns emerge. Geodynamically, the two Bundelkhand fields are marginal-craton intrusions localised where the ~1.1 Ga Kaimur cover thinly blankets Archaean basement, whereas Behradih is an intracratonic, basement-hosted field at the core of the Bastar Craton - demonstrating that both craton-margin and craton-core settings are productive in central India. Petrologically, all three depart from archetypal kimberlite, but in different directions: transitional kimberlite-orangeite-lamproite at Majhgawan, unclassifiable hybrid (metasomatised-mantle group) at Bunder, and true orangeite at Behradih; collectively they argue that the Indian subcontinental mantle yields dominantly ultrapotassic, phlogopite-rich magmas rather than CO₂-rich archetypal kimberlite. Temporally, an approximately one-billion-year gap separates the two magmatic cycles, with distinct triggers (Rodinia-related far-field stress versus Deccan plume). Economically, the fields form a maturity sequence - a producing mine (Majhgawan), a fully evaluated but undeveloped world-class resource (Bunder), and an advanced prospect (Behradih) - while their diamond populations (small, resorbed, colourless-to-brown, commonly plastically deformed stones) are broadly comparable, consistent with derivation from deformed cratonic roots.

Table 1: Comparative summary of the Majhgawan, Bunder and Behradih (Mainpur) diamond fields of central India

Attribute	Majhgawan (Panna)	Bunder (Chhatarpur)	Behradih / Mainpur (Gariaband)
Craton / state	Bundelkhand Craton; Madhya Pradesh	Bundelkhand Craton; Madhya Pradesh	Bastar Craton; Chhattisgarh
Location	~20 km SW of Panna town (~24°39'N, 80°02'E)	Near Buxwaha, ~80 km SSW of Majhgawan (~24°15'N, 79°20'E)	Behradih village, Mainpur area, Gariaband district (~20°12'N, 82°12'E)
Tectonic position	Southern craton margin beneath Vindhyan cover	Southern craton margin beneath Vindhyan cover	Core of the Bastar craton, near Chhattisgarh basin margin
Country rock	Kaimur Group sandstone (Vindhyan) on ~2.5 Ga granite basement	~1.1 Ga Kaimur Group platform sediments (Vindhyan)	Archaean Bastar granitoids (with 3.5-3.6 Ga crustal nuclei nearby)
Bodies in field	2 (Majhgawan, Hinota)	7 (Saptarshi cluster; Atri principal)	6 (Behradih, Kodomali, Payalikhanda, Jangra, Kosambura etc.); Behradih largest
Pipe size / facies	~500 × 370 m; diatreme facies, shallow erosion	Steep-sided pipes; multiphase pyroclastic infill (Atri S + N)	~300 × 160 m; diatreme facies (Tokapal to the south preserves crater facies)
Rock classification	Olivine lamproite lapilli tuff; transitional kimberlite-orangeite-lamproite ("majhgawanite")	Non-diagnostic; lamproite-orangeite mineralogy with kimberlite-like Sr-Nd; metasomatised-mantle group	Orangeite (Group II kimberlite) - first well-documented occurrence outside the Kaapvaal Craton; Kodomali also viewed as lamproite-like
Emplacement style	Explosive phreatomagmatic-pyroclastic diatreme	Multiphase pyroclastic pipes; Atri N post-dates Atri S	Volatile-rich explosive diatreme with pelletal lapilli
Age	~1074 Ma (Ar-Ar phlogopite 1073.5 ± 13.7 Ma; Rb-Sr 1067-1044 Ma)	~1080 Ma (Rb-Sr phlogopite 1079 ± 6 Ma; 1064 ± 15 Ma)	~65 Ma (Ar-Ar whole rock + U-Pb perovskite); Kodomali ~62 Ma
Period / event	Mesoproterozoic (Stenian); Rodinia-assembly pulse	Mesoproterozoic (Stenian); same ~1.1 Ga pulse	End-Cretaceous-Palaeocene (K-Pg); synchronous with Deccan flood basalts (Réunion plume)
Diamond grade / endowment	~8-13 cph; producing mine	~0.7 ct/t; ~37 Mt, ~27.4 Mct inferred at Atri	Diamondiferous at exploration stage (34 macro- + 86 microdiamonds in drillcore); grade not yet defined to mine standard

Diamond character	Small white-brown; gem + industrial mix	White-brown, plastically deformed; octahedra + resorbed dodecahedra	Mostly colourless (minor brown, pale yellow); resorbed micros; N contents 358-950 at. ppm
Discovery status /	Alluvials mined since ≥13th century; NMDC mechanised mine since 1958-68	Rio Tinto discovery 2004; auctioned to Essel Mining 2019; development pending clearances	Located during DGM/GSI prospecting (1990s-2000s); advanced prospect, no mine yet; associated Mahanadi-Pairi alluvial workings

Future Prospects of Central Indian Kimberlite-Clan Exploration

Bundelkhand Craton

The most immediate opportunity is the revival of the Bunder project, whose ~27.4 Mct Atri resource would, if developed responsibly, multiply Indian diamond output many times over; resolution of the Buxwaha forest and groundwater questions is the critical path. At Majhgawan, deepening of the existing pit and re-evaluation of the Hinota pipe and surrounding conglomerate horizons could extend life of mine. Regionally, the 80-km Vindhyan-covered corridor between Bunder and Majhgawan - and the wider Kaimur outcrop tract along the entire southern craton margin - remains underexplored for concealed pipes; the 2004 discovery of an entire seven-pipe cluster under forested cover shows that surface prospecting alone has not exhausted the belt. High-resolution airborne magnetic and gravity-gradiometry surveys, systematic stream-sediment indicator-mineral sampling (chromite, Cr-diopside, phlogopite chemistry, given the garnet-poor nature of these transitional magmas), and re-examination of minor alkaline occurrences of the Son valley (e.g., Jungel, Angor) constitute logical next steps.

Bastar Craton

In the Mainpur field, only Behradih and Kodomali have received modern petrological and diamond study; Payalikhanda, Jangra and Kosambura warrant systematic delineation, microdiamond analysis and bulk sampling to establish grades, and the field as a whole requires a compliant resource estimate. The recognition that Mainpur magmatism is end-Cretaceous and plume-related opens a genuinely new search space: coeval pipes may exist beneath the Deccan Traps to the west and beneath the Proterozoic Chhattisgarh, Khariar and Indravati basin margins, where cover defeats conventional prospecting but modern geophysics and basal-cover indicator sampling can see through. The Mahanadi-Pairi alluvial diamond trains should be inverted as vectors to further concealed sources, and the large-tonnage, low-grade Tokapal crater system merits re-assessment with current recovery economics.

Cross-cutting scientific and policy priorities

Three province-scale priorities apply to both cratons. First, lithosphere mapping: seismic tomography and mantle-xenocryst thermobarometry should be integrated to outline where the lithosphere is, and was, thick enough (>140-150 km) to host diamond, thereby ranking ground ahead of drilling. Second, geochronology-led targeting: with two proven emplacement epochs (~1.1 Ga and ~65 Ma), structures reactivated at those times - craton-margin faults for the former, plume-related fracture systems for the latter - are the most prospective conduits. Third, an enabling framework: transparent auctions of exploration blocks, continuity between reconnaissance and mining tenure, and early, genuine environmental and community engagement (the central lesson of Buxwaha) are as decisive for India's diamond future as any geological factor. Given that India presently contributes only a negligible share (~0.05%) of world diamond production while possessing two diamondiferous cratons, one producing mine, one world-class undeveloped resource and one untested field, central India must be regarded as one of the most underexplored diamond provinces on any Archaean craton.

IV. Conclusion

Central India contains three primary diamond fields on two cratons: Majhgawan-Hinota and Bunder on the Bundelkhand Craton, and Behradih (Mainpur field) on the Bastar Craton. Emplacement is polycyclic: the Bundelkhand fields formed at ~1.08-1.07 Ga (Mesoproterozoic, Rodinia-assembly pulse), whereas Behradih-Kodomali formed at ~65-62 Ma, synchronous with Deccan volcanism and plume-lithosphere interaction. All three fields are explosive diatreme-facies pipes, yet none is an archetypal Group I kimberlite: Majhgawan is a transitional 'majhgawanite', Bunder is an unclassifiable metasomatised-mantle hybrid, and Behradih is an orangeite - the first documented outside the Kaapvaal Craton. The comparative analysis defines a maturity sequence - mine (Majhgawan), undeveloped resource (Bunder, ~27.4 Mct), advanced prospect (Behradih) - with broadly similar diamond populations across all three. Future prospects are substantial: concealed-pipe search beneath Vindhyan, Chhattisgarh-basin and Deccan cover, systematic evaluation of the remaining Mainpur pipes, revival of Bunder, and lithosphere-scale targeting together make central India a premier frontier for diamond exploration in the 21st century.

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