Detrital Zircons Reveal Evidence of Hadean Crust in the Singhbhum Craton, India

Scott R. Miller,[1,⋆] *Paul A. Mueller,*[1] *Joseph G. Meert,*[1] *George D. Kamenov,*[1] *Anthony F. Pivarunas,*[1] *Anup K. Sinha,*[2] *and Manoj K. Pandit*[3]

1. Department of Geological Sciences, University of Florida, Gainesville, Florida 32601, USA; 2. Dr. K. S. Krishnan Geomagnetic Research Laboratory, Chamanganj Bazaar, Allahabad 221 505, India; 3. Department of Geology, University of Rajasthan, Jaipur, Rajasthan, India

ABSTRACT

The Singhbhum craton is one of five Archean cratons constituting the Indian subcontinent. It consists of four major lithotectonic units with broadly defined ages from Eoarchean to Neoarchean: the Older Metamorphic Group (3.7–3.2 Ga), Older Metamorphic Tonalite Gneisses (3.8–3.1 Ga), Singhbhum Granite (3.5–3.0 Ga), and Iron Ore Group (3.51–2.55 Ga). In this study, 270 zircons were separated from modern sediment of the Baitarani River, which is wholly contained within the craton. Zircons were analyzed with laser ablation ICP-MS for their U-Pb systematics; >50% were less than 5% discordant. Three primary age groupings account for ~98% of analyses: 3.62–3.55 Ga (5%), 3.50–3.22 Ga (87%), and 3.10–3.06 Ga (6%). The preponderance of 3.50–3.22 Ga zircons is consistent with the local basement that includes a 3.47 Ga tonalite gneiss enclave within a 3.35–3.30 Ga outcrop of the Singhbhum Granite near Keonjhar. Lu-Hf systematics of zircons yielded 67% with positive initial εHf scattered above and below the mantle growth curve and 33% with negative initial εHf, indicating contributions from both depleted mantle and older crustal sources. Single-stage model ages range from 4.29 to 3.10 Ga. Of note is a single zircon with a ^{207}Pb/^{206}Pb age of 4015 ± 9 Ma (1.3% discordant), which is the first Hadean zircon documented from any of the Indian cratons. This grain yielded an initial εHf of −5.30, which indicates an episode of Hadean felsic crust formation in the Singhbhum craton comparable to that proposed for the Jack Hills of the Yilgarn craton (Australia).

Online enhancements: supplemental tables.

Introduction

Eoarchean and Hadean detrital zircons are often found in areas where similar-aged crust has not been preserved and exposed. For example, Hadean zircons from the Jack Hills of the Yilgarn craton (Australia) were recovered from metasupracrustal rocks deposited ~3.6 Ga. In other cases, for example, the Slave craton, the oldest reported detrital zircons are not as old as the oldest documented crust (Bowring and Williams 1999; Sircombe et al. 2001; Iizuka et al. 2006). In the Jack Hills, the Hadean zircons constitute ~3% of the zircons recovered (Harrison et al. 2017). Despite extensive surveys of zircons in modern river and beach sands derived from ancient cratons, Hadean U-Pb ages and Lu-Hf model ages are rare (e.g., Rino 2004, 2008; Yang et al. 2009; Iizuka et al. 2013). Natural dispersion and sorting of zircon in modern sediment enables rapid, regional-scale surveys of crust formation ages and evolutionary characteristics. In this study, we present U-Pb and Lu-Hf analyses of detrital zircons from modern river sediments collected from the Baitarani River basin of the Singhbhum craton and hypothesize the potential of individual Singhbhum cratonic units as zircon sources.

The Singhbhum Craton

Singhbhum Craton Lithologies. The Singhbhum craton is among the smallest of India's five distinct cratonic nuclei (40,000 km^2; Mishra et al. 1999). Limited mapping and disparate ages complicate differen-

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⋆ Author for correspondence; e-mail: scottrimiller@ufl.edu.

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tiation among the proposed lithotectonic units: the Older Metamorphic Group (OMG), Older Metamorphic Tonalite Gneisses (OMTG), Singhbhum Granite (SG), and Iron Ore Group (IOG). Each of these units crops out within the Baitarani River catchment delineated by Verma and Jha (2015; fig. 1). Apart from the SG, each unit hosts a diversity of rock types, further challenging genetic interpreta-

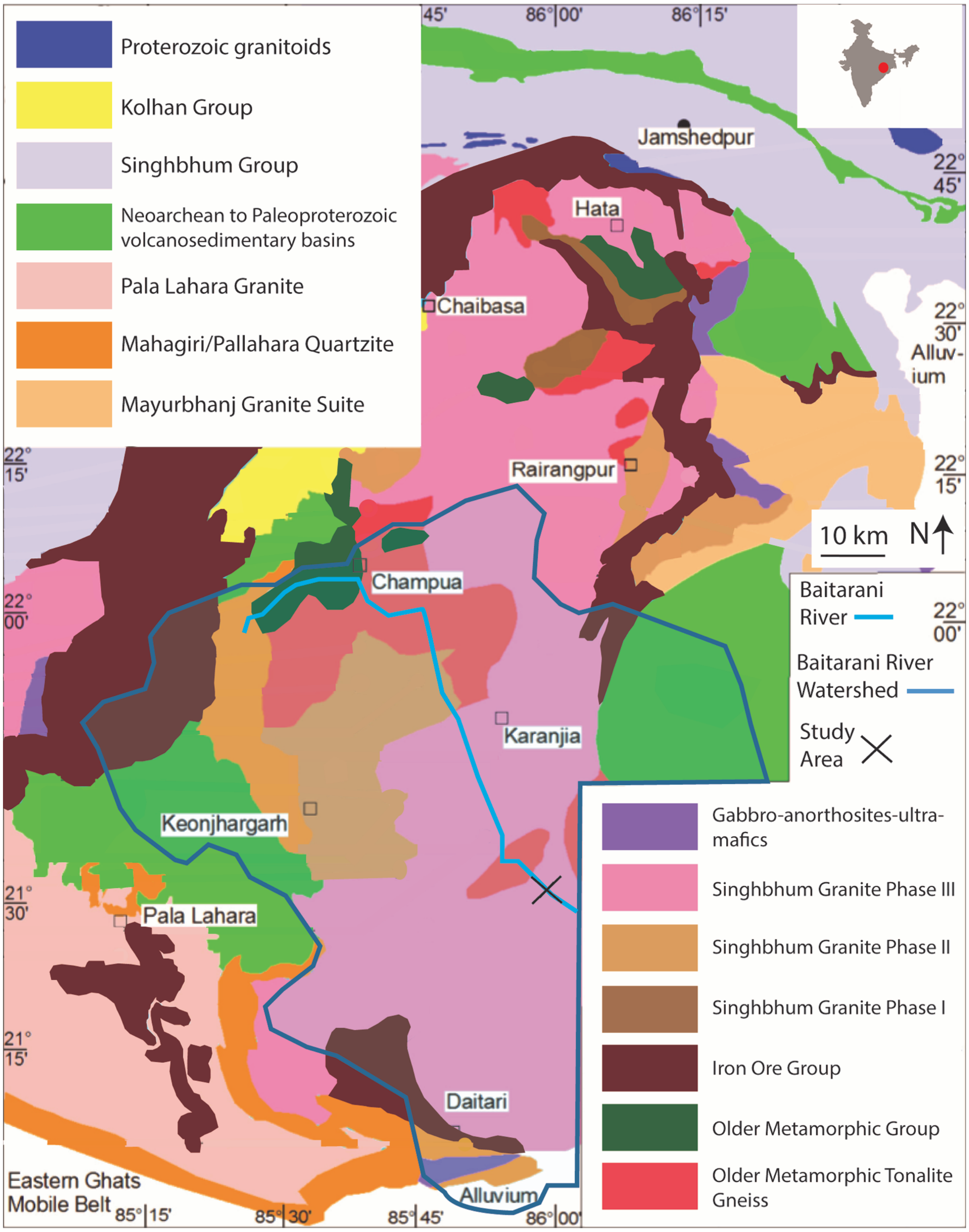

Figure 1. Generalized map of the Singhbhum craton, with inset map of India (modified from Dey et al. 2017, originally from Saha 1994). A cross indicates the sample site, while the cyan line denotes the Baitarani River, and the dark blue line and transparent polygon delineate the Baitarani River watershed.

tions. A complex web of interpretations has been garnered from subjective relative age determinations between units (see Mazumder et al. 2012; Hofmann and Mazumder 2015) and is not within the scope of this study. Instead, we follow major-unit descriptions with an outline of absolute age determinations through the Archean to highlight (1) their broad age ranges and (2) the difficulty in assigning a provenance for zircons from modern river sediment.

The OMG consists of a variety of amphibolite-grade rocks with igneous and sedimentary protoliths. Garnetiferous quartzites and other metasedimentary rocks, including biotite-muscovite pelitic schists, quartz-sillimanite/quartz-muscovite schists (potential sandstone protolith), and quartz-magnetite-cummingtonite schists (potential banded iron formation [BIF] protolith; Ray et al. 1987; Saha 1994; Saha et al. 2012; Hofmann and Mazumder 2015) are limited to enclaves within the SG, mostly exposed in the type section near Champua (fig. 1).

The limited outcrops of the OMTG have been mapped extensively around Champua as small enclaves within the SG (fig. 1). The presence of igneous rocks in the OMTG and the tendency for authors to refer to foliated metamorphic OMTG rocks by their presumed igneous protolith has resulted in a confusing terminology for these rocks (Sharma et al. 1994; Mishra et al. 1999; Nelson et al. 2014; Upadhyay et al. 2014). The OMTG near Champua consists of granodioritic, tonalitic, and granitic gneisses and amphibolites that were intruded by pegmatite and younger doleritic dikes of the Newer Dolerite dike swarm at 2.25 and 1.77 Ga (Shankar et al. 2014; Hofmann and Mazumder 2015; Srivastava et al. 2016).

The SG occupies ~10,000 km^2 and forms the nucleus of the Singhbhum craton. Saha and Ray (1984) divided the SG into 12 intrusive bodies on the basis of geography and three phases on the basis of crosscutting relationships and geochemistry sans radiometric data. SG phase I is dominated by granodiorite-trondhjemite, while phases II and III are K-rich granodiorites to monzogranites (Dey et al. 2017). Saha and Ray (1984) also divided SG into A (phases I and II, originally assigned an age of ~3.30 Ga) and B (phase III, originally assigned an age of ~3.10 Ga) types on the basis of rare earth element (REE) chemistry (Saha 1994; Meert et al. 2010). Dey et al. (2017) noted that chemical differences do not indicate distinct episodes of emplacement and that data from Nelson et al. (2014) indicate distinct overlap of phases at ~3.33 Ga. Dey et al. (2017) further described two large portions of the SG as porphyritic (phase II) and nonporphyritic (phase III). Our sample site lies within the nonporphyritic SG (fig. 1).

Singh et al. (2016) described the IOG (fig. 1) as a greenstone belt with phyllite and ferruginous quartzite along with unmetamorphosed to weakly metamorphosed tuffaceous shale, BIFs, ferruginous quartz arenite, argillite-dolomite, ultramafic-mafic-felsic volcanic rocks, ultramafic layered intrusions, chert, shale, and minor carbonate (Saha 1994; Bose 2000; Misra 2006; Mondal 2009; Mukhopadhyay et al. 2012). Mukhopadhyay et al. (2008, 2012, 2014) identified massive quartzites in the southern (Mahagiri Quartzite) and western (Pallahara-Mankaharchua Quartzite) IOG as distinct from the bulk IOG ultramafic and greenstone assemblage on the basis of the presence of a paleosol between the quartzites and an underlying SG intrusion into the IOG. As cliff formers, these quartzites produce the most prominent and laterally extensive outcrops in the western and southern IOG (fig. 1).

Archean Ages for the Singhbhum Craton. Misra (2006), Mohanty (2012), and Roy and Bhattacharya (2012) provided detailed time lines of published ages for major units of the Singhbhum craton, including U-Pb monazite, ^{87}Rb/^{86}Sr, and ^{147}Sm/^{144}Nd whole-rock (WR) isochrons. Ages from WR isochrons in the Archean are problematic (e.g., Moorbath et al. 1986). Therefore, an accurate Eo- to Mesoarchean geochronological history of the Singhbhum craton warrants comparison between only the most robust U-Pb single-zircon ages (including errors, as discussed below; fig. 2). To include the broadest range of possibilities for each unit, we did not discriminate between differences in reporting style (i.e., single-grain vs. single-sample vs. multisample averages, number of analyses, etc.). These geochronological data indicate large overlaps, suggesting synkinematic intrusion and deformation for the SG/OMG/OMTG (Singh et al. 2016). Because of the considerable spread of ages, we refrain from attempting to discern individual pulses of magmatism in the SG and metamorphism in the OMG/OMTG.

The only U-Pb single-zircon Eoarchean ages reported from the Singhbhum craton come from Cameca IMS-4f ion microprobe analysis of three grains with ages of 3628 ± 72, 3583 ± 50, and 3591 ± 64 Ma from an OMG orthoquartzite (Goswami et al. 1995). Paleoarchean ages dominate the Singhbhum craton zircon signal of every major unit and begin at ~3.5 Ga for all except the OMG. These include a 3527 ± 17 Ma U-Pb upper intercept from 40 analyses on 28 zircon grains in the NE Singhbhum OMTG tonalite-trondhjemite-granodiorite gneisses (Thermo Elemental VG3 ultraviolet laser ablation [LA]-ICP-MS; Acharyaa et al. 2010), a 3496 ± 5 Ma single-grain ^{207}Pb/^{206}Pb age for the phase II SG near our sample site (SHRIMP-II ion

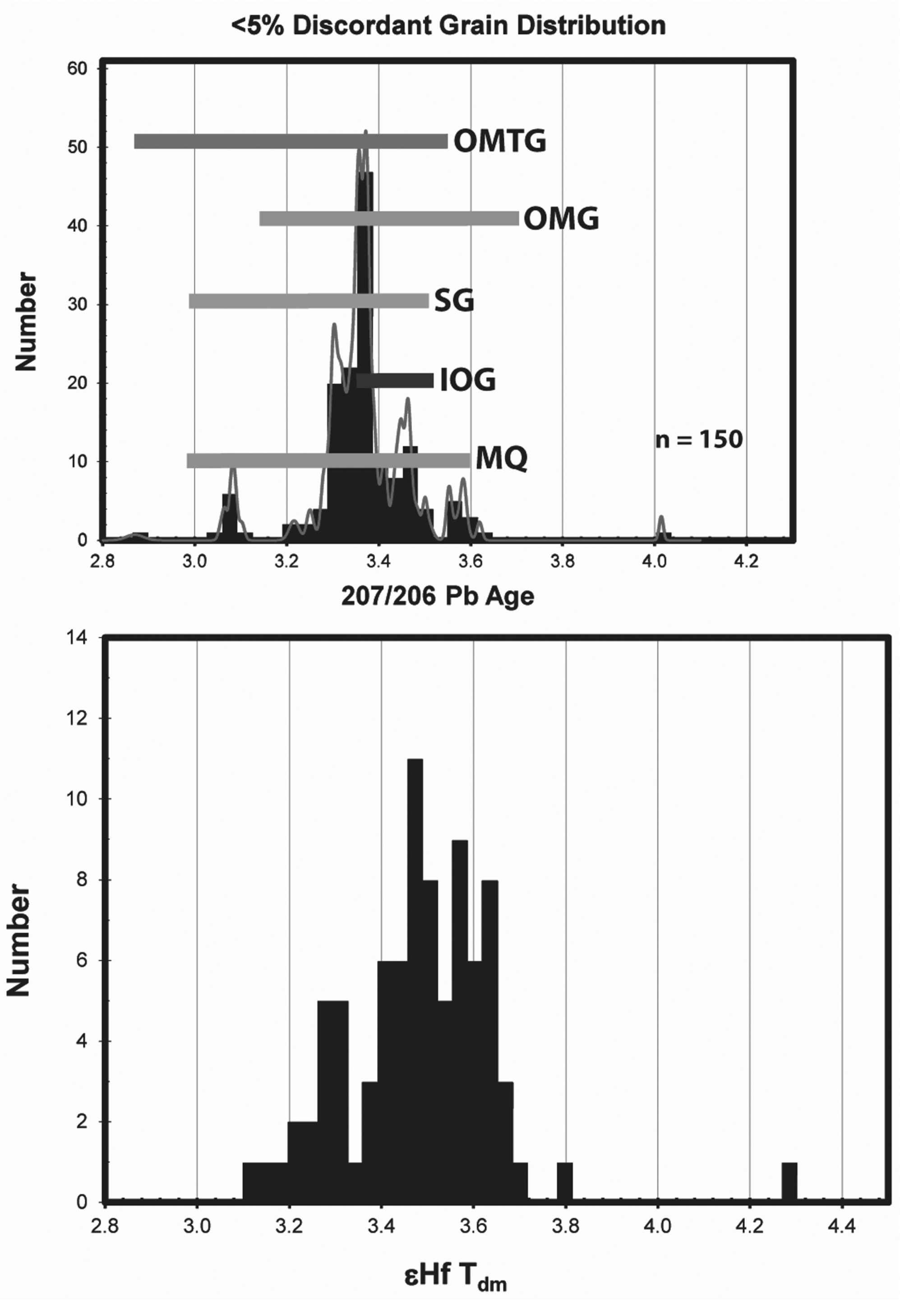

Figure 2. *Top*, horizontal bars: amalgamation of U-Pb single-zircon ages from the Singhbhum craton for the Older Metamorphic Tonalite Gneisses (OMTG; Mishra et al. 1999; Acharyaa et al. 2010; Nelson et al. 2014; Upadhyay et al. 2014; Dey et al. 2017), the Older Metamorphic Group (OMG; Goswami et al. 1995; Mishra et al. 1999), the Singhbhum Granite (SG; Mishra et al. 1999; Tait et al. 2011; Nelson et al. 2014; Upadhyay et al. 2014; Dey et al. 2017), the Iron Ore Group (IOG; Basu et al. 2008; Mukhopadhyay et al. 2008), and the Mahagiri Quartzite (MQ; Mukhopadhyay et al. 2014). Extent of horizontal bars represent the extent of ages to 2σ error. Vertical bars: probability density plot (PDP) of 150 <5% discordant ^{207}Pb/ ^{206}Pb ages from zircon cores with three groupings, at 3.62–3.55 Ga (5%), 3.50–3.22 Ga (87%), and 3.10–3.06 Ga (6%). Bin count = 40. *Bottom*, Hf T_{DM} ages for 86 <5% discordant zircon cores. The Hadean grain shows a T_{DM} = 4.29 Ga. Bin count = 40. The PDPs in this figure were generated with ISOPLOT (Ludwig 2003). A color version of this figure is available online.

microprobe; Tait et al. 2011), a $^{207}Pb/^{206}Pb$ average age of 3507 ± 2 Ma for 12 zircons from a dacitic lava in the southern IOG (SHRIMP-II ion microprobe; Mukhopadhyay et al. 2008), and multiple single-grain $^{207}Pb/^{206}Pb$ ages for the Mahagiri and Pallahara-Mankaharchua Quartzites as old as 3578 ± 18 Ma (LA-ICP-MS; Mukhopadhyay et al. 2014). Because of their gneissic character, data from the Patna Tonalite within the SG (LA-multicollector [MC]-ICP-MS; Dey et al. 2017) are included in the OMTG age range.

Lower age limits for major Singhbhum units are dominantly Mesoarchean. The youngest OMG orthoquartzite is ~3.2 Ga (fig. 2; Goswami et al. 1995). Upadhyay et al. (2014) reported a 2790 ± 27 Ma average age for SG phase I zircons, and Basu et al. (2008) provided an age of 3392 ± 29 Ma from 22 zircon analyses from a tuff in the eastern IOG. The comprehensive survey of detrital zircons in the Mahagiri and Pallahara-Mankaharchua Quartzites (seven sample locations, $n > 400$) by Mukhopadhyay et al. (2014) yielded ages as young as 3016 ± 22 Ma.

Methods

A 1.5-kg sample of river sand was taken from a dry riverbank approximately 50 km ESE of Keonjhar, Odisha (fig. 1). Samples were milled to <2.0 mm and hand-sieved to yield a <300-μm split. Fines were then decanted in water. Zircons were separated with standard magnetic (Frantz LB-1 Magnetic Barrier Laboratory Separator) and heavy-liquid (tetrabromoethane) techniques. Samples were mounted in epoxy resin with FC-1 standard zircon and polished before backscattered-electron (BSE) and cathodoluminescence (CL) imaging with an EVO MA10 XVP scanning electron microscope. Analytical procedures for U-Pb and Lu-Hf follow those in Mueller et al. (2008). U-Pb measurements were made by LA using an Applied Spectra tandem 213 nm Nd-YAG laser attached to a Nu Plasma multicollector inductively coupled plasma mass spectrometer (LA-MC-ICP-MS) and guided by CL and/or BSE images. All ages discussed exhibit less than 5% discordance without common-Pb correction. Fifty-seven percent of the grains that were less than 5% discordant ($^{207}Pb/^{206}Pb$) were analyzed for their Lu-Hf systematics, also by LA with the Nu Plasma MC-ICP-MS (Mueller et al. 2008). A 40-μm beam was placed adjacent to the location of the U-Pb ablation in the same domain analyzed for U-Pb. U-Pb data were reduced with CALAMARI (P. A. Mueller) and Lu-Hf data were reduced with ISOTOPIA (P. A. Mueller), assuming a decay constant of $\lambda = 1.867 \times 10^{-11}$/year (Söderlund et al. 2004), the chondritic values of Bouvier et al. (2008) for bulk earth, and a linear evolution model for the depleted mantle (Mueller et al. 2008).

Results

Zircons were typically subrounded to prismatic and elongate (fig. 3*b*–3*f*), and most lacked zoning in CL images. When observed, zoning was oscillatory, indicative of an igneous origin (fig. 3*a*, 3*b*; Corfu et al. 2003). In a few cases, zircons displayed multistage zoning (fig. 3*e*, 3*f*) and patchy zoning, but other metamorphic textures, such as fir-tree structures and flow structures, were not observed (Corfu et al. 2003).

Including the 26 grains subjected to multiple ablations, 162 of 294 (57%) U-Pb measurements yielded ages less than 5% discordant, with no indication of common Pb (table S1; tables S1, S2 are available online; fig. 4). Every <5% discordant core/rim analysis yielded overlapping ages within 2σ error bounds, providing no evidence for multiple magmatic events. Therefore, rim data were not considered in subsequent plotting and analysis. For analyses less than 5% discordant, three age groups are apparent in a probability density plot (fig. 2): 3.62–3.55 Ga (5%), 3.50–3.22 Ga (87%), and 3.10–3.06 Ga (6%). All grains displaying oscillatory zoning fit within these groups. In addition, one Hadean grain of 4015 ± 9 Ma age (1.3% discordant) and one Mesoarchean grain of 2870 ± 38 Ma (0.8% discordant) are reported. The Hadean grain (fig. 3*g*, 3*h*) is broken and subrounded without distinct internal structure in its CL image.

Eighty-six zircons were analyzed for Lu-Hf, with εHf calculated relative to the bulk silicate earth $^{176}Hf/^{177}Hf$ value of 0.28279 (fig. 5; Bouvier et al. 2008; table S2). The depleted-mantle (DM) linear model is from Mueller et al. (2008). Data are scattered, with ~67% of grains producing a positive initial εHf, indicating that zircon parental magmas were a mixture of both enriched and depleted reservoirs. The three age groupings 3.62–3.55 Ga (5%), 3.50–3.22 Ga (87%), and 3.10–3.06 Ga (6%) all exhibit a range of εHf values (vertical arrays in fig. 5), indicating involvement of enriched and depleted sources. An initial εHf of −5.30 for the 4015 Ma grain indicates an enriched, likely crustal, influence on its parent magma. Twelve analyses plot above the DM model, indicating that (the model) underestimates εHf evolution, alteration of the initial Lu/Hf system, and/or an incorrect (older) age. An incorrect model is likely, as ^{204}Pb counts per second and $^{204}Pb/^{206}Pb$ ratios indicate little influence of common Pb on these ages. It should be noted, however, that the DM model used is tied to a typical εHf of mid-ocean ridge basalt (+16), rather than to

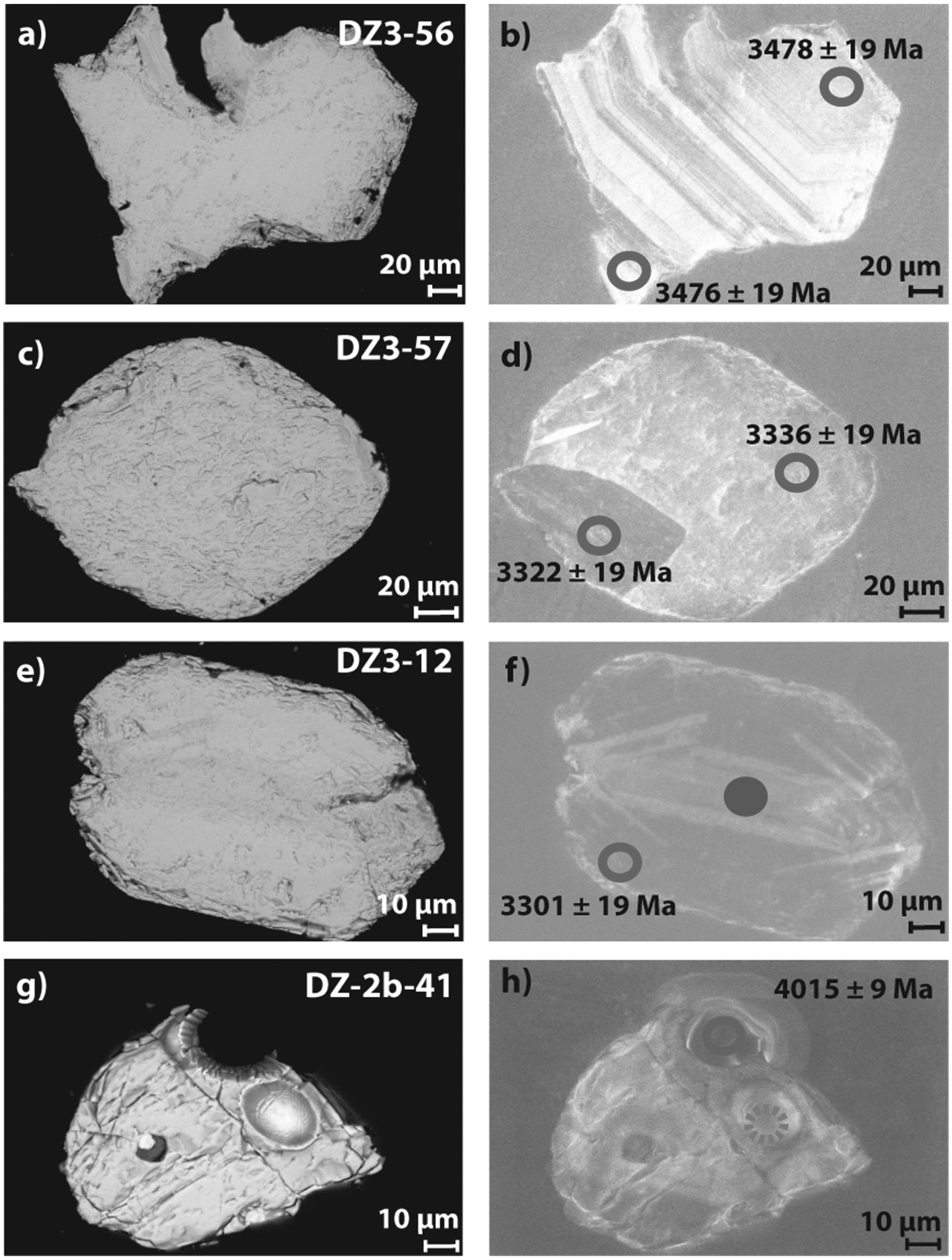

Figure 3. Preablation backscattered-electron (black background) and cathodoluminescence (gray background) images displaying zircon morphology and structure. Open circle = satisfies discordance threshold; filled circle = does not satisfy discordance threshold; stippled circle = Lu-Hf ablation site. *a*, *b*, Fragmented morphology and oscillatory zoning indicating a broken piece from a much larger zircon; both core and rim satisfy the discordance threshold. *c*, *d*, Composite grain core and rim are of the same age and meet the discordance threshold, indicating a magmatic origin. *e*, *f*, Oscillatory zoning with a concordant rim and a discordant core. *g*, *h*, 4015 Ma zircon (DZ-2b-41) with ablated area to the top right and Lu-Hf spot below. Although the zircon is fractured, no disturbance to the isotopic system via fluid introduction is indicated. There are potential inclusions to the left of main fracture in the grain, away from spot analyses. A color version of this figure is available online.

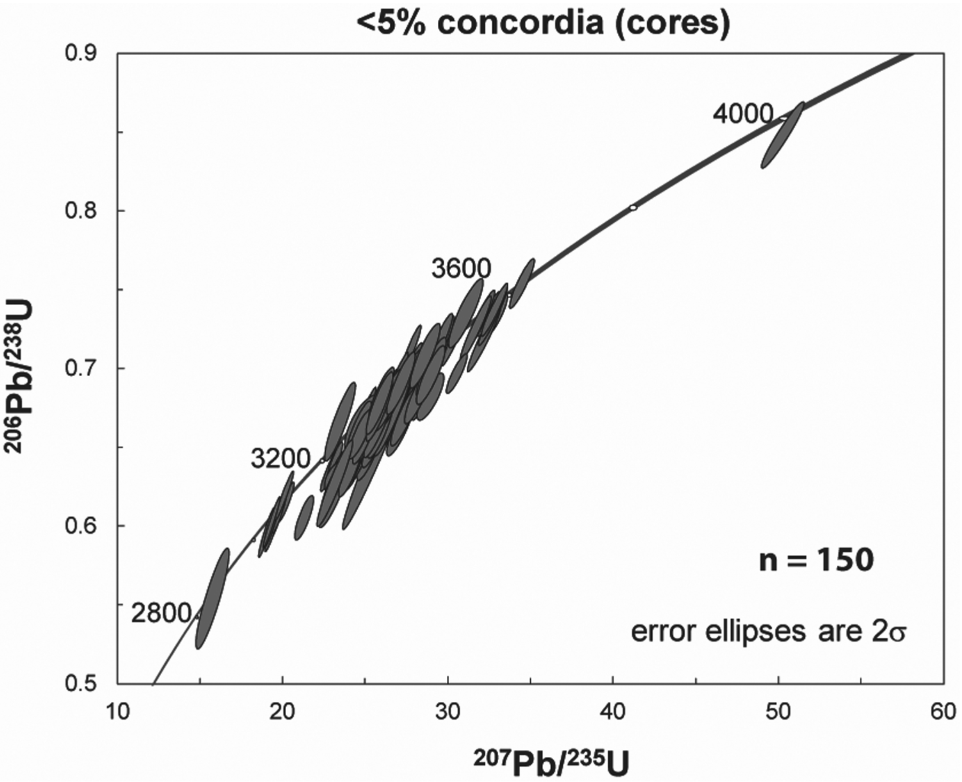

Figure 4. U-Pb concordia of 150 zircon cores (56% of 270 grains analyzed) at <5% discordance. Zircon rim ages were within error of core ages and are not included in the diagram. Figure was generated with ISOPLOT (Ludwig 2003). A color version of this figure is available online.

higher values (+23; Andres et al. 2004), so that values greater than the evolution line at any time are to be expected.

Discussion

Zircon Sources in Singhbhum Craton. The Baitarani River catchment (Verma and Jha 2015) is fully encompassed by the Singhbhum craton (fig. 1). The following qualitative assessments are made by comparing results of this study to the watershed delineation of Verma and Jha (2015) and previously published ages. Our results are broadly similar to those of Mukhopadhyay et al. (2014), who reported major age peaks at ~3.1–3.2, ~3.25–3.35, and ~3.4–3.5 Ga and minor peaks at >3.0 and <3.6 Ga for the Mahagiri and Pallahara-Mankaharchua Quartzites. Our 3.50–3.22 Ga grouping (87% of analyses) overlaps with published ages in the catchment, including 3471 ± 24 Ma (tonalite gneiss: Patna Tonalite), 3347 ± 35 Ma (porphyritic granite: Keonjhar Granite), and 3304 ± 25 Ma (nonporphyritic granite: Karanjia granite) ages from Dey et al. (2017), and 3496 ± 5 and 3291 ± 9 Ma ages from Tait et al. (2011) for the Keonjhar Granite. Because these lithologies of the SG are exposed in the river basin upstream of our sample area, we infer that a large proportion of zircon grains are from the SG. A magmatic parent is underscored by prismatic morphologies and identical ages for core and rim in oscillatory-zoned grains.

The 3.10–3.06 Ga (6%) ages are potentially from the SG, OMTG, or Mahagiri Quartzite, on the basis of overlap with ages reported by Upadhyay et al. (2014) and Mukhopadhyay et al. (2014). The ~2.8 Ga grain could be from the SG, the OMTG, or a minor unit such as the Dhanjori volcanics (Misra and Johnson 2005; Acharyya et al. 2010; Upadhyay et al. 2014). Because the OMG, OMTG, SG, IOG, and Mahagiri Quartzite all have >3.5 Ga U-Pb-dated zircon grains, the exact source of prismatic to subrounded 3.62–3.55 Ga (5%) grains and the anhedral 4015 Ma grain are unclear. However, BIF pebbles and cobbles were found in portions of the Baitarani River near our sampling site, indicating a potential IOG component. Although no Hadean ages have been documented in the Singhbhum before this study, Eoarchean $^{147}Sm/^{143}Nd$ T_{DM} model ages as old as ~3925 and ~3950 Ma have been ascertained from minor units of the Singhbhum craton west of the western IOG, including trondjhemite xenoliths in

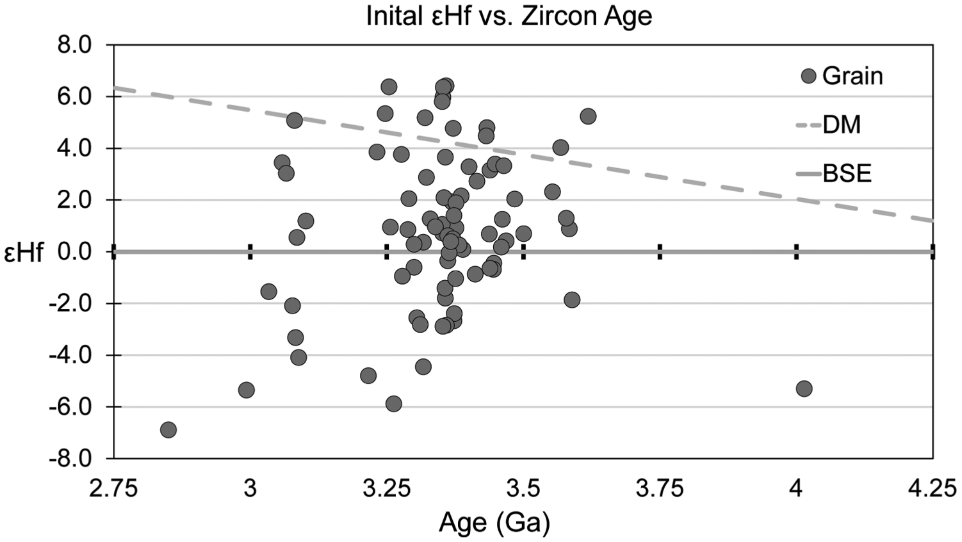

Figure 5. Initial εHf versus ^{207}Pb/^{206}Pb age for a subset of <5% discordant grains. Samples plotting above the depleted-mantle (DM) model indicate an incorrect model, alteration of the Lu/Hf ratio, and/or an incorrect age. Assuming equal relative abundances on Earth and chondrites, BSE (bulk silicate earth) = CHUR (chondrite uniform reservoir) for Hf (Bouvier et al. 2008). A color version of this figure is available online.

the Bonai pluton (considered as part of SG phase II) and the Darjing group metasediments (Sengupta et al. 1996; Saha et al. 2004).

Tectonic History of the Singhbhum Craton. There is considerable debate regarding the Singhbhum craton's Archean tectonic evolution. Models produced from a variety of Singhbhum craton units using (largely) relative REE abundances include a plume origin (Sharma et al. 1994), vertical "blob" tectonics (Nelson et al. 2014; Dey et al. 2017), and modern-style tectonism with subduction (Saha et al. 2004; Mukhopadhyay et al. 2008, 2012; Acharyaa et al. 2010; Tait et al. 2011; Manikyamba et al. 2015; Singh et al. 2016). Our data exhibit a dominantly mixed initial εHf signal for Paleoarchean zircons and a predominantly mantle source for grains with age ~3.5 Ga (fig. 5). Single-stage Lu-Hf T_{DM} values cluster at less than ~3.7 Ga. The initial εHf values are compatible with proposals for juvenile contributions to the nearby Patna Tonalite (Hf T_{DM} = 3551 ± 15 Ma) and younger granitic country rock (Hf T_{DM} = 3463 ± 16 Ma [porphyritic] or 3460 ± 16 Ma [nonporphyritic]) from Dey et al. (2017). Positive initial εHf signatures reported by Dey et al. (2017) contributed to their conclusion that the Singhbhum craton originally formed as an oceanic plateau and evolved to a progressively more alkaline upper crust as a result of crustal recycling driven by magmatic underplating and vertical tectonics. Conversely, Tait et al. (2011) used the Sm-Nd system to report a less significant juvenile component for the ~3.3 Ga Keonjhar Granite (SG phase II) on the basis of initial εNd values near +1. Combined with low high-field-strength elements, enriched large-ion lithophile elements/light REEs, and high Si content, they interpreted SG formation to represent arc magmatism at a continental margin. From Sm/Nd ratios, magmas derived from juvenile mantle sources have been identified in the Singhbhum craton at ~3.1 Ga in the Bangur gabbro (Augé et al. 2003), ~2.7–2.8 Ga in the Dhanjori volcanics (Roy et al. 2002), and ~2.2 Ga in the Dhanjori Formation (De et al. 2015). The continued production of mantle-derived material may suggest the presence of vertical tectonics in the Singhbhum craton throughout the Archean. However, it is noteworthy that geochemical data indicating an arc signature have been reported in the OMG/OMTG/IOG and throughout the bulk of crust-forming time in the Archean (see references above). The 86% of initial εHf values less than DM (and 33% negative initial εHf) suggest crustal components in the Singhbhum craton throughout the Archean and into the latest Hadean (fig. 5).

Global Cratonic Relations at ~4 Ga. Hadean (>4.0 Ga) zircons have been found in nine distinct areas on Earth (Li et al. 2016; Harrison et al. 2017 and references therein). The growing inventory of ancient zircon locations implies either (1) multiple locations for early crust formation or (2) a geographical link between cratons as primary sources for zircons. Only three of these areas (Yilgarn craton, Wyoming craton, and Slave craton) yielded zircon specimens from in situ metamorphic rocks of Paleoarchean-Eoarchean age and so are most likely to have indigenous sources (Compston and Pidgeon 1986; Mueller et al. 1998; Wilde et al. 2001; Wyche et al. 2004; Iizuka et al. 2006, 2007, 2009; Cavosie et al. 2007; Harrison 2009; Mueller and Wooden 2012; Thern and Nelson 2012; Nebel et al. 2014; Valley et al. 2014). In other areas, Hadean zircons are present in Proterozoic and younger units as either constituents of sedimentary rocks or xenocrysts in volcanic assemblages and so are of less certain cratonic origins (e.g., Wang et al. 2007; Nadeau et al. 2013). Data presented here suggest that the Singhbhum craton may also be a cratonic source for Hadean zircons.

The εHf data from >4.0 Ga detrital zircons in the Yilgarn craton suggest a protracted history of crustal evolution (Amelin et al. 1999; Blichert-Toft and Albarède 2008; Harrison et al. 2008; Kemp et al. 2010; Nebel-Jacobsen et al. 2010; Zeh et al. 2014). Contemporaneous Wyoming craton data suggest a slightly more chondritic initial εHf at 4.0 Ga, though still indicating the presence of an enriched, crustal component that evolved throughout the Archean (Mueller et al. 1998; Mueller and Wooden 2012), while slightly younger (Eoarchean) Slave craton data indicate both crustal and mantle contributions (Iizuka et al. 2009). An initial εHf of -5.3 for this study's Hadean grain indicates felsic crust formation before 4015 Ma, either adding another locale for early crustal differentiation or indicating a past connection to other cratons. Nutman et al. (2015) proposed the supercontinent Itsaqia at 3.66 Ga from a global correlation of gneissic rocks, and Mueller et al. (1992) interpreted a synchronous 3.96 Ga age ascertained from Wyoming craton zircons and the Acasta Gneiss of the Slave craton as evidence for their original unity. However, because of a lack of data linking the Singhbhum craton to the Yilgarn, Wyoming, or Slave cratons in the Hadean, we propose the Singhbhum as a distinct locale for Hadean crustal formation.

Conclusions

An expansive geologic history and diverse assemblage of preserved rock units, combined with limited outcrop, has led to an ongoing debate regarding the history of the Singhbhum craton. U-Pb and Lu-Hf analyses of detrital zircons from modern river sediment conducted in this study provide a unique, broad-scale picture of Singhbhum evolution. In the Paleoarchean to early Mesoarchean, a mixture of mantle and crustal magma sources dominates the initial εHf signal of the nearby SG crust and the detrital zircon suite reported here. This study is among the first geochronologic surveys of modern river sediment in India and marks the first occurrence of a Hadean zircon in modern river sediment at ~4.0 Ga. Our findings validate multiple suggestions that the Singhbhum craton is the oldest in the Indian subcontinent (Basu et al. 1981; Saha et al. 2004), An initial εHf of -5.3 for the Hadean grain suggests that it was derived from Hadean continental crust, marking the Singhbhum craton as one of the oldest cratons on Earth.

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