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To cite this version:
Carlos E. Ganade, Pierre Lanari, Daniela Rubatto, Joerg Hermann, Roberto F. Weinberg, et al.. Magmatic flare-up causes crustal thickening at the transition from subduction to continental collision. Communications Earth & Environment, 2021, 2, 10.1038/s43247-021-00103-z. insu-03661280

HAL Id: insu-03661280
https://hal-insu.archives-ouvertes.fr/insu-03661280
Submitted on 6 May 2022

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Magmatic flare-up causes crustal thickening at the transition from subduction to continental collision

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Above subduction zones, magma production rate and crustal generation can increase by an order of magnitude during narrow time intervals known as magmatic flare-ups. However, the consequences of these events in the deep arc environment remain poorly understood. Here we use petrological and in-situ zircon dating techniques to investigate the root of a continental arc within the collisional West Gondwana Orogen that is now exposed in the Kabyé Massif, Togo. We show that gabbros intruded 670 million years ago at 20–25 km depth were transformed to eclogites by 620 million years ago at 65–70 km depth. This was coeval with extensive magmatism at 20–40 km depth, indicative of a flare-up event which peaked just prior to the subduction of the continental margin. We propose that increased H2O flux from subduction of serpentinized mantle in the hyper-extended margin of the approaching continent was responsible for the increased magma productivity and crustal thickening.

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Continental arcs are produced by subduction magmatism. Determining their internal dynamics is a key to understanding the formation of continental crust. At mid to deep crustal levels, continental arcs comprise dominantly magmatic additions from the mantle, pre-existing metasedimentary rocks, and various basement rocks of the upper plate. Exposed tilted arc sections offer a unique opportunity to understand the deeper arc environment, such as those of the Salinian arc and Faminatian arc, which expose 5–30 km of the arc crustal column. Deeper sections, such as the Fiordland arc of New Zealand (15–55 km), show a gradual transition from shallower plagioclase-bearing igneous cumulates and granulite facies rocks to plagioclase-free, garnet-rich rocks (i.e., garnet-pyroxenites) and to eclogites.

Although there is a consensus that lower arc garnet-pyroxenite and eclogite protoliths are derived from mantle magma additions to arcs, there remains considerable controversy about the mechanism of formation of these plagioclase-free, garnet-rich lithologies. Their formation has implications for the origin of magmas in convergent plate margins. The most accepted models for the origin of garnet-pyroxenites in arc rocks argue either that they represent high-pressure cumulates from a mantle-derived hydrous basalt or basaltic andesite, or that they are partial melting residues (restites) reflecting high pressure crystal–liquid equilibria at lower arc levels.

On the other hand, documentation from deep exposure of the Kohistan paleo-island arc (Northern Pakistan) is consistent with the formation of the lower arc garnet granulite by dehydration-melting of upper arc hornblende gabbro-norite leading to intracrustal differentiation and arc thickening to 30 km.

Crustal thickening to more than 50 km in Andean-type arcs is caused by complex processes that are as yet poorly-understood and involve a combination of tectonic shortening and magmatic accretion. Igneous inflations have been postulated based on petrological investigation to explain arc thickening in other continental arcs such as in the Coast Plutonic Complex and Sierra Nevada of North America, Fijian arc, and also in the Kohistan arc in Pakistan.

Rates of magma addition in continental arcs are temporally discontinuous and characterized by short flare-ups, lasting 5–35 million years, and during which magma addition rates are up to fifteen times higher than background rates. Ignition of flare-ups in arcs is an unresolved question with explanations ranging from upper plate crustal processes driven by internal arc feedback to episodic mantle melting and dynamic processes involving lithospheric thickening and delamination. Flare-ups have so far been documented in upper crustal sequences, using the abundance of igneous rocks and their ages, detrital zircon ages of sedimentary rocks derived from the arc, and volume estimates of plutonic and volcanic rocks. There has not yet been a detailed documentation of the consequences of these events to the deeper portion of the arcs. Although deep arc xenoliths offer important perspectives and their investigation has generated P-T paths, geochronology data, and even cooling rates, they return only random and punctuated information compared to exposed continental arc sections.

Here, we use petrochronology and thermodynamic simulations of lithologies from three different levels of the Kabýe Massif arc exposed in Togo, to show that deep parts of the arc were being pushed down into high pressure regions and internally reworked, while voluminous magma was being emplaced in the upper parts of the arc during a flare-up. Thus, we report for the first time the record and consequences of the flare-up phenomenon in deeper arc portions, responsible for doubling crustal thickness.

**Sampling deep continental arc crust.** The magmatic rocks of the continental arc system of the West Gondwana Orogen intruded the old continental rocks of the Benino-Nigerian shield which extend to NE Brazil. This shield and its arc formed the overriding plate during continental collision with the West African Craton. The Kabýe lower arc section is now preserved along the collisional suture zone and was exhumed to the surface by west-verging thrusts, along with ultra-high pressure eclogites, during the subduction of the West African craton margin (Fig. 1A).

Shallow plutonic equivalents of the Kabýe lower arc section can be found in other sections of the West Gondwana Orogen, such as the Santa Quitéria plutonic arc complex in NE Brazil, and in its continuation in northwest Africa (Fig. 1A). This arc system started as early as 880–800 Ma with juvenile magmatic additions, and culminated with voluminous batholith growth during the mature arc stage at 660–620 Ma. Regardless of the arc level, the mafic rocks of the Kabýe Massif display positive εNd values at 600 Ma, ranging between 0 and +9 and low 87Sr/86Sr ratios from 0.7015 to 0.7051. However, age-correlated felsic granitoids from the shallow mature stage of the Santa Quitéria arc, display increasingly negative εNd values and higher 87Sr/86Sr towards younger ages from 650 to 610 Ma. Such dispersion of isotopic values has been interpreted as progressive contamination of juvenile magmas by a continental upper plate, as the arc thickened from 660 to 610 Ma. Together with regional geochronology of the shallow arc-related granitoids from NE Brazil and Togo, mature continental arc activity started at 660–640 Ma and finished with the final West Africa Craton passive margin subduction at c. 610 Ma.

The root of the Kabýe arc was formed by mantle-derived magmatism and now has a layered structure and comprises essentially deep meta-igneous and igneous rocks, that are exposed in a tectonically segmented monoclinal framework dipping 35–45° to the east (Fig. 1B). Despite the several west-verging thrusts that crosscut it, disrupting the stratigraphic arc column, the massif still preserves an excellent semi-continuous exposure of the lower to middle arc section with primary igneous layering. The trace element systematics of the rocks is in agreement with a continental arc setting. Metamorphism and rock composition vary systematically across the massif. Garnet-pyroxenite lenses within strongly foliated garnet granulite dominate the western lower unit (the arc root) and grade into garnet-free metamorphosed pyroxenites, norites and diorites crosscut by kyanite-garnet-bearing felsic dykelets. The mafic granulites, originally metabasalts, from the lower unit are composed of garnet-clinopyroxene-plagioclase ± orthopyroxene with subordinate rutile and quartz, where garnet overgrows clinopyroxene indicating increasing pressure conditions. These lower arc rocks are often mimetic with residual garnet-pyroxenite accompanied by quartz-rutile-zoisite ± kyanite and retrogressive amphibole in association with plagioclase-rich leucosomes. The middle unit is composed of garnet-free orthopyroxene-clinopyroxene-plagioclase ± rutile ± quartz granulites and minor garnet-bearing granulites and garnet-free clinopyroxenites. Finally, in the upper unit, xenoliths of garnet-bearing metabasalts occur within garnet-free metabasalts, which in turn have a conspicuous primary compositional igneous layering overprinted by a concordant metamorphic foliation.

We selected four samples from three different crustal levels of the tilted Kabýe continental arc for integrated petrology and geochronological investigation (see Detailed petrography and thin-section mapping in Supplementary items). Samples DKE-374 and DKE-371 are both anatetic high-pressure mafic rocks from the lower arc zone: DKE-374 represents the residual high-pressure eclogitic assemblage of garnet and clinopyroxene (Fig. 1B) while DKE-371 is a garnet-bearing, plagioclase-rich leucosome (Fig. 1C). Additionally, sample DKE-375 is a foliated...
Results: pressure-temperature (P-T) conditions and zircon geochronology. Thin sections of all garnet-bearing samples were compositionally mapped with EPMA to determine the chemistry zoning of minerals, and to derive the local bulk composition for forward and iterative P-T modeling. Figure 2 illustrates the approach taken for the most interesting garnet-pyroxenite sample (DKE-374). For samples DKE-371 and DKE-375 see Supplementary Fig. S1. The mineral assemblage map shows large idiomorphic garnets that are surrounded by interstitial pyroxene, amphibole, and quartz. Compositional maps show homogenous composition for the pyroxene with XNa (Na/(Na + Ca) = 0.26) and XMG (Mg/(Mg + Fe) = 0.76) with a little rimward increase of the XMg, thus classifying it as omphacite and the rock as an eclogite. Garnet is zoned with a more homogenous core with Alm49.47Py31.28Gr25.18Sp0.16-0.14 and a rim with Alm46.42Py27.21Gr30.26Sp0.13-0.09 (Fig. 2A).

Forward P-T modeling for this eclogite sample (DKE-374), using the local bulk composition of the mapped thin section, predicts the observed assemblage defining a P-T field between 1.60 and 2.25 GPa and 670–875 °C. The intersection of compositional isopleths of garnet and omphacite rims is between 1.86–2.10 GPa and 805–820 °C, yielding an average P-T condition of 815 ± 20 °C and 2.0 ± 0.2 GPa (Fig. 2B and Supplementary File Fig. S2). Our modeling indicates that amphibole is a retrograde phase. Iterative P-T modeling using the program Bingo–Antidote28 integrated in XMapTools 29 defines a P-T region between 800 °C, 1.8 GPa and 900 °C, 2.5 GPa where there is a good match between observed assemblages and compositions, with optimal P-T conditions of 820 °C, 2.15 GPa (Fig. 2B and Supplementary File Fig. S3). Forward and iterative P-T modeling...
is then formed during near-isobaric cooling. Al-in-hornblende eclogite facies conditions. Forward modeling results for the samples from different arc levels. The background isochemical phase diagram, calculated using the composition of the upper arc, garnet-free metababbro of sample TO-140 from ref.3, shows different late stage alteration was removed from the integrated pixel composition used in the forward and inverse modeling for P-T equilibration after intrusion of the gabbro at 1.2 GPa. The estimated pressure for the eclogite sample DKE-374 indicates a maximum depth of ~67 km (using 33.3 km depth. These data indicate preservation of an arc section from 70 to 20 km, similar to that described in the Fiordland arc of New Zealand. 

Zircon U-Pb ages coupled with trace element analysis for the shallower arc eclogite (sample DKE-371) are rounded with sector zoning, typical of high-grade rocks. Their very low U (2 ppm), Th/U (0.03–0.005) and trace element contents are comparable to the low-Yb group of sample DKE-374. The zircon Concordia age for this sample is 619.6 ± 9.8 Ma (2σ) for this sample is 619.6 ± 9.8 Ma (2σ). The age is interpreted to date crystallization of the partial melt within the lower arc crust. 

Zircon grains recovered from the plagioclase-rich leucosome (sample DKE-371) are rounded with sector zoning, typical of high-grade rocks. Their very low U (2–15 ppm), Th/U (0.03–0.005) and trace element contents are comparable to the low-Yb group of sample DKE-374. The zircon Concordia age for this sample is 619.6 ± 9.8 Ma (2σ), which is within error of the age of the low-HREE metamorphic zircon rims in eclogite DKE-374 (Fig. 3B). The age is interpreted to date crystallization of the partial melt within the lower arc crust. 

U-Pb ages and zircon trace element patterns for the shallower garnet metababbro (sample DKE-375) and quartz-diorite (sample DKE-380) are less complex. Their zircons have oscillatory zoning and REE patterns of typical igneous grains. The ages, therefore, constrain the crystallization of the protolith of the garnet metababbro and quartz-diorite at 620.0 ± 5.9 and 623 ± 15 Ma, respectively (Supplementary Fig. S5). This magmatic event is recorded by samples DKE-374 and DKE-371. The zircon REE pattern for DKE-375 indicates limited or no garnet growth during crystallization of the magma, considering that zircon is a late crystallizing phase (Supplementary Fig. S5). Therefore, we interpret that in this sample garnet formed at subsolidus conditions during near-isobaric cooling at 1.2–1.4 GPa. While isobaric cooling can lead to minor garnet growth, it is impossible that it completely consumes plagioclase, which is indeed absent in
The flare-up event was active c.10 million years prior to the collision with the passive margin of the West African Craton, which is marked by ultra-high pressure (UHP) eclogites dated at c. 610 Ma\textsuperscript{22}. During this 10 million years time interval, 500 km of lithosphere would have been subducted at average plate velocities of 5 cm year\textsuperscript{-1}. This distance is in accordance with the width of the hyper-extended modern Iberian passive margin, that exposes serpentined sub-continental lherzolitic mantle over a 170 km wide section\textsuperscript{36}. One of the features of the preserved passive margin of the West African Craton is the abundance of serpentined peridotites interpreted to mark a continental-ocean transition zone\textsuperscript{37–39}. Subduction of these serpentinites and release of H\textsubscript{2}O during antigorite and chlorite breakdown at 80–120 km depths can increase the H\textsubscript{2}O flux to the subarc mantle by a factor of six compared to expected flux from breakdown of hydrous phases in altered oceanic crust\textsuperscript{40,41}. This scenario is modeled in Fig. 5A where different lithospheric segments enter the subduction zone during transition from subduction to collision. Up to about 20 million years prior to collision, oceanic lithosphere is subducted where hydrous phases are concentrated in the mafic oceanic crust. This is followed by subduction of the ocean-continent transition zone that is dominated by serpentinites. Finally, the extended continental margin enters the subduction zone, leading to continental collision. The different water content of the subducted lithospheric segments controls partial melting of the subarc mantle, and hence magmatic addition to the upper arc environment. For the normal oceanic lithospheric water content (0.17 × 10\textsuperscript{9} g of H\textsubscript{2}O) is assumed to be stored in a 2 km-thick upper volcanic layer of altered basalts (lawsonite-eclogite, 1 wt% H\textsubscript{2}O) and a 3 km-thick layer of peridotites with an average serpentinization of 10%. For the exhumed mantle in the hyperextended margin, the water content (1.07 × 10\textsuperscript{9} g of H\textsubscript{2}O) is stored in a 3 km-thick upper zone of fully serpentined peridotite with a progressive decrease of serpentinization to 70, 40, 20, and 10% to 7 km\textsuperscript{-42} and assuming 9 wt% H\textsubscript{2}O stored in the serpentinites at sub-arc depth\textsuperscript{43}. In the calculations we use a vertical section with a unit area of 1 m\textsuperscript{2}, thus this number represents the quantity of water in a column of 1 m\textsuperscript{2} at sub-arc P–T conditions. The response of the arc to the varying magma production driven by these varying H\textsubscript{2}O inputs in the hot...
mantle wedge is illustrated in the lower panel of Fig. 5A. With time, the arc thickens with accumulation of mantle-derived magmas at the neutral buoyancy level, favored by subduction of water-rich, serpentinized mantle that ignites the magmatic process as constrained by our samples is ~70 km.

We suggest that this increased H₂O flux ignited the magmatic flare-up immediately preceding collision. In the Gangdese arc, in South Tibet, a similar flare-up immediately predating collision has also been recorded. There, continental arc magmatism associated with the Tethyan oceanic lithosphere subduction lasted for c. 160 million years, until continental collision between India and Asia shut down the system, marked by the Kagan and Tso Morari UHP eclogites dated at 50–45 Ma. In this context, a similar flare-up event is evident 5–10 million years before UHP metamorphism associated with subduction of the Indian passive margin. The similar history in West Gondwana and Himalayan orogens suggests that geometry and composition of the transitional region between ocean and continents modulates the intensity of magmatism in the period immediately preceding continental collision.

Using thermodynamic simulations, we modeled the progressive transformation of an upper arc gabbro to an anatectic residual eclogite due to burial in response to magmatic inflation resulting from a flare-up. The mineral assemblage and modes observed in sample DKE-374 are modeled at 800–850 °C and 1.9–2.0 GPa using the upper arc gabbro composition TO-140 from ref. 3. (Fig. 5B). Burial leads to an increase in density from 3.0 g cm⁻³ in the gabbro to up to 3.4 g cm⁻³ in the eclogite. As the ignition of the flare-up and thickening of the arc crust was immediately followed by subduction of the continental margin at 615–610 Ma (Fig. 6A), we speculate that, despite the high density of the eclogites in the arc roots, there was not enough time for the instability to develop into delamination. Moreover, the dragging down of buoyant incoming continental crust at the start of the collision provided a support and a natural barrier that impeded eclogite delamination. The thickening of the arc was likely accompanied by compressive forces, as is common in other continental arcs, however the relative contributions of tectonic shortening and magma inflation to crustal thickening could not be estimated. Although the densification of the arc root could lead to the enhanced compression in the upper arc, there is still no clear indication that this process could also generate low pressure gradients in the arc column that would favor magmas to stall at the neutral buoyancy zone. During and after continental collision at c. 610 Ma, thrusting toward the west exposed the deep roots of the continental arc at 600–580 Ma. Thrusting was coupled with dextral transcurrent tectonics along the suture zone, and was responsible for displacing the batholith-dominated zone to the present-day NE Brazil (Fig. 6B, C).

This is the first study that recognizes the impact of a magmatic flare-up on the roots of continental arcs. The flare-up combined with background compressive tectonic stresses led to a significant crustal thickening. Thus, we conclude that magmatic flare-up causing inflation in arcs represents a new and alternative model to explain thick arc roots and the origin of garnet-pyroxenites and eclogites in their deep sections. Detailed P–T–time evolution of exhumed arc roots provides an important link between processes in the lower crust with those in upper crust. The results presented provide insights into the interplay of fast crustal growth and thickening in response to a magmatic flare-up at the termination of a long-lived subduction system.

Methods

Mineral chemistry and quantitative petrological maps. The samples were analyzed by electron probe micro-analyser (EPMA) using both quantitative spot analyses and X-ray compositional mapping in wavelength-dispersive mode (Supplementary Information). EPMA analyses were acquired with a JEOI JXA-8200 superprobe at the Institute of Geological Sciences (University of Bern and Federal University of Rio de Janeiro, the latter only for plagioclase and amphibole of sample DKE-380). Conditions for spot analyses were 15 keV accelerating voltage, 10 nA beam current and 40 s dwell times (including 2 × 10 s of background measurement). The following standards were used: almandine (Si, Fe, and Al), forsterite (Mg), orthoclase (K), anorthite (Ca), albite (Na), tephrite (Mn) and ilmenite (Ti) for garnet, and wollastonite (Si), orthoclase (K), anorthite (Al, Ca), albite (Na), forsterite (Mg), almandine (Fe), tephrite (Mn), and ilmenite (Ti) for pyroxene and amphibole. Compositional maps follow the procedure described in ref. 47 using 15 keV accelerating voltage, 100 nA beam current and dwell times of 200 ms. Three maps of 1000 × 1000 pixels over areas of 15 × 15 mm² were acquired on samples DKE-374, DKE-371 and DKE-375 (Fig. 2 and Supplementary File Fig. S1). Point analyses were measured on the same day by using the software XMapTools 2.3.1 (Supplementary Data 1). Local bulk compositions (Supplementary File Fig. S3) were approximated from combined oxide weight percentage
maps using the export built-in function of XMapTools by integrating the pixel compositions of particular domains after a density correction50,51.

Imaging of internal zoning. Zircons were separated from the crushed rock samples using usual heavy liquid and magnetic techniques. Grains were mounted in epoxy resin and polished down to expose the near-equatorial section. Imaging of zircon grains was acquired at the Research School of Earth Sciences (RSES), at the Australian National University, and at the Geochronological Research Center (CPGeo), at the University of São Paulo (USP). Cathodoluminescence (CL) imaging at RSES was done in a JEOL-6610A scanning electron microscope (SEM) supplied with a Robinson detector for cathodoluminescence. Operating conditions for the SEM were 15 kV, 70 mA and a 20 mm working distance. In São Paulo, CL images were obtained using a Quanta 250 FEG SEM prepared with a Centaurus Mono CL3 detector for cathodoluminescence.

Sensitive high-resolution ion micro probe. Zircon grains were analysed for U, Th, and Pb in the epoxy mount using the SHRIMP-II at the Research School of Earth Sciences (RSES) at the Australian National University (ANU) and the SHRIMP-II at the University of São Paulo. SHRIMP II conditions and data acquisition were generally as described previously52. Each data point was collected in sets of six scans throughout the masses and a reference zircon (TEM2)53 was analyzed for the calibration. U-Pb data were collected over three analytical sessions using the same standard, with the different sessions having calibration uncertainties between 1.21% and 2.11% (2-sigma), which was propagated to single analyses.

Forward thermodynamic modeling. Pseudosections (isochronal sections) were constructed using the THERIAK-DOMINO software60 (version 04.02.2017) with the internally consistent thermodynamic data of ref.54. Modeling was performed using eight-components for sample DKE-375 in the system Na₂O-CaO-MgO-Al₂O₃-SiO₂-H₂O-O₂.K₂O and MnO were not considered in the models due to lack of mica, K-feldspar and negligible spessartine in garnet. The following solid solution models were used in pseudosection modeling: garnet, orthopyroxene, spinel and mcl62, ilmenite-hematite63, amphibole64, omphacite65, feldspars66, epidote, talc, and chlorite60. Pure phases included rutile, Al₂SiO₅ isomorphs and H₂O. The bulk compositions used were calculated from the compositional maps. The pseudosection of anhydrous DKE-375 sample was calculated in the P-T window of 0.5-2.0 GPa and 600-1100 °C, for equilibrium assemblage composed of garnet, clinopyroxene, plagioclase, quartz, rutile, and Fe-Ti oxides. For sample DKE-374, a P-MH₂O model was calculated to evaluate the effects of water in bulk composition at fixed temperature of 750 °C based on unpublished Zr-in-rutile thermometry. The amount of water varies from anhydrous conditions at the left-hand side (H₂O = 0.001 wt% normalized) to hydrated conditions (H₂O = 2.09 wt% normalized) at the right-hand side. The pseudosection of sample DKE-374 was calculated using MH₂O = 0.06 (equivalent to 0.13 wt% of H₂O normalized) in the P-T window of 1.0–2.5 GPa and 600–1100 °C, looking for metamorphic peak assemblage composed of garnet, omphacite, quartz, epidote, rutile, and melt. Tiny amount of extra oxygen (O = 0.001 mol) was added to the bulk composition of both samples in order to stabilize the ferric-bearing end-members of solid solution models. The peak P-T conditions were calculated using isopleth interception thermodarometry and the average results are reported at 95% of confidence level.

Forward thermodynamic simulation. A computer model ArcMod based on a dynamic evolution of the reactive bulk composition during prograde metamorphism was developed to simulate the solid-state transformation and melt production of a rock unit during burial and heating in continental arc settings. This model simulates for a set of P-T trajectories and for a variety of rock systems, the progressive changes in (1) mineral assemblages, (2) mineral and melt compositions, (3) melt and solid bulk chemistry, (4) rock density. The thermodynamic model relies on Gibbs energy minimizations performed using THERIAK55, and the most up-to-date thermodynamic datasets and activity models for mafic rocks67,68. ArcMod includes three additional subroutines that can adjust the reactive bulk com
composition at every step to maintain $\text{H}_2\text{O}$ saturation at subsoludus condition, to simulate water-fluxed melting and/or melt extraction. Each bulk rock composition was treated as a separate system without any possible interaction between them. The numerical strategy is described in the following. Firstly, ArcMod computes the minimum $\text{H}_2\text{O}$ content required for water saturation at the starting subsoludus conditions. This value is applied to maintain water saturation conditions with only 0.01 vol% excess water at the first iteration. Then, if a $\text{H}_2\text{O}$ fluid phase is predicted to be stable at any step, the corresponding $\text{H}_2\text{O}$ content is fractionated from the reactive bulk composition before performing the next iteration. This ensures that water saturation is maintained throughout the subsoludus space but without producing a pure $\text{H}_2\text{O}$ phase above the permeability threshold of 0.01 vol%. Melt extraction occurs in the model when the melt fraction exceeded an arbitrary threshold fixed at 7 vol%. The rock is assumed to retain a fraction of 1 vol% of melt at the end of each extraction stage. A volume factor, representing the volume of the reactive system after $\text{H}_2\text{O}$ and/or melt extraction, is approximated after each iteration. The amount of $\text{H}_2\text{O}$ in the melt was monitored and maintained above the threshold of 6 wt% in order to simulate water-fluxed melting. When required, the bulk $\text{H}_2\text{O}$ was increased (by adding external $\text{H}_2\text{O}$ fluid), to raise the amount of $\text{H}_2\text{O}$ in the melt to the threshold value of 6 wt%. Note that water-fluxed melting is only predicted to occur at pressure above 2.2 GPa for the $\text{P}$–$\text{T}$ trajectory shown in Fig. 5B. Results of ArcMod are presented as mod-box diagrams depicting the evolution of the volume fraction of solids, in addition to the total amount of silicate differentiation to intermediate or felsic arc rocks may occur in several levels but predominantly in the neutral buoyancy zone, represented by the quartz-diorite sample DKE-380. Fluid release from serpentinized mantle triggered mantle melting and arc flare-up. Continental collision at c. 610 Ma and subduction of the West African Craton and associated passive margin to depths of UHP metamorphism (>90 km), leading to onset of exhumation and upper plate uplift. Exhumation (600–580 Ma) through thrust zones and exposure of deep arc roots of the Kabýé Massif. Continuous shortening due to Himalayan-type continental collision results in the formation of the major (>4000 km long) right-handed Transbrasiliano-Kandi strike-slip system.

**Data availability**

All data generated during the study, including in-situ zircon U-Pb combined with trace element and mineral EPMA analyses are available in supplementary information file (Supplementary Data 1 and 2). Bulk-geochemistry used in thermodynamic modeling in Figs. 2B and 5B as well as trace elements in Fig. 4A are available in ref. 24. Age distribution of detrital and igneous zircons from arc-related basins and granitoids from Togo and NE Brazil in Fig. 4B are available in refs. 23,26,27,34,35. The datasets generated during this study are available in the Figshare repository (https://figshare.com/s/6e68304663ac213a7e and https://figshare.com/s/52c03f498957575e249f).

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**Acknowledgements**

This research was supported by the Serrapilheira Institute (grant # Serra—1709-21887), Swiss National Science Foundation project N IZESO_194628 and by the Geological Survey of Brazil. C.E.G. acknowledges the CAPES Higher Education Improvement Coordination 88881.363575/2019-01 for supporting the author’s research visit at the University of Bern. C.E.G and C.M.R thank Julio Cezar Mendes for the help in the EPMA data of sample DKE-380.

**Author contributions**

C.E.G, P.L., D.R., J.H. and R.F.W. equally contributed in project conceptualization, idea refinement and writing. C.E.G., M.A.S.B., R.C. and Y.A. collected the samples and field data. C.E.G. and D.R. acquired U-Pb ages and zircon trace elements. P.L., C.E.G., and L.R.T. acquired EPMA data and performed the thermodynamic modeling. C.M.R. acquired EPMA data for sample DKE-380.

**Competing interests**

The authors declare no competing interests.

**Additional information**

**Supplementary information** The online version contains supplementary material available at https://doi.org/10.1038/s43247-021-00103-z.

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**Peer review information** Primary handling editor: Joe Aslin.

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