J. Indian Inst. Sci.
A Multidisciplinary Reviews Journal
ISSN: 0970-4140 Coden-JIISAD

REVIEW ARTICLE

Review on Age of Magmatism and Crust Formation in Sri Lanka: U–Pb and Lu–Hf Isotopic Perspectives

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Abstract | Recent studies on zircons at high resolution separated from metamorphosed rocks of igneous origin of the four tectonic domains of Sri Lanka by Lu–Hf and U–Pb isotope systematics have shed light upon its tectono-magmatic history. While providing better insights, the new dataset is not contradictory with Nd-model ages and U–Pb zircon dates discovered from Sri Lanka in early 90s. These new data suggest that both Wanni (WC) and Vijayan (VC) Complexes were magmatic arcs with the former being relatively older than the latter, and the Kadugannawa Complex (KC) is a marginal arc magmatic suite in the vicinity of WC. The oldest Highland Complex (HC) has been derived of Mesoproterozoic to Archean crustal and subducted sedimentary components. The Lu–Hf systematics of rocks from the HC record the oldest Hf-crustal model age of ~ 3.5 Ga and highly negative εHf(t)(t) values (up to − 30) inferring contribution of older subducted sediments and/or crustal components. In the WC and KC tectonic units, variable εHf(t) of zircon from negative to positive values from gneisses indicate the involvement of both juvenile mantle components and older continental materials in the generation of the arc-related magma with Hf-model ages from ~ 700 to 2800 Ma. On the other hand, the meta igneous rocks of the VC have distinct positive εHf(t) data with Hf-modal ages in the range of ~ 700–1600 Ma supporting entirely a juvenile origin. During the Neoproterozoic to Cambrian (ca. 700–500 Ma), the HC has predominantly served as a suture zone for the collision of the WC and VC arcs. This suggests that the Sri Lankan terrains were juxtaposed at an active continental margin setting associated with two-staged subduction during the Gondwana amalgamation. The metamorphism took place during the Neoproterozoic in the entire basement up to the granulite facies conditions reaching intermittently ultra-high temperature (UHT) conditions.

Keywords: *Magmatism, Crust formation, Gondwana, U–Pb and Lu–Hf systematics, Sri Lanka*

1 Introduction

The Sri Lankan Precambrian is one of the high-grade terrains with enormous international interest in all aspects of geology due to its central position within the east Gondwana Supercontinent. This has made the island subjected to numerous studies by many experts during the last few decades (e.g., [41] and references therein). Particularly, after Milisenda et al. [42], several workers presented various scenarios and models to understand tectonic amalgamation of the litho-tectonic units of Sri Lanka during the supercontinent

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Springer IISc Press

Gondwana assembly. Similarities in tectonic style, degree of metamorphism and Neoproterozoic U–Pb ages have been used to suggest common Pan-African tectonothermal evolution for the lower crustal domains of southern India, Sri lanka and Lutzow-Holm Bay of east Antarctica (e.g., [2, 5, 16, 57, 64]).

Early workers (e.g., [1, 6–9, 11, 66, 68]) divided the crystalline basement of Sri Lanka into different crustal or lithological subdivisions/units, mainly based on petrolography and structural geological features. However, later studies introduced detailed petrological, geochemical and geochronological characteristics to classify the Sri Lankan basement rocks (e.g., [10, 22, 32, 42, 43, 52]). The boundaries of the rock units were also revised extensively resulting in the current nomenclature presented in Cooray [10]. Thus, based majorly on Kröner et al. [32, 36], Milisenda et al. [42, 43], Voll and Kleinschrodt [67] and Hölzl et al. [23], the Sri Lankan basement was classified into four units, namely Highland Complex (HC), Wanni Complex (WC), Kadugannawa Complex (KC) and Vijayan Complex (VC) (Fig. 1; [10]). Although the boundaries of the HC–VC and HC–KC are clearly discernible in the field as shear/thrust contacts, that between the HC and WC remains undecided due to lack of obvious geological terrain markers. Hence, the HC–WC boundary is merely an 'inferred boundary' defined by contrasts in isotopic values or mainly Nd-model ages of Milisenda et al. [42, 43].

The HC which forms a major part of the Sri Lankan metamorphic basement (Fig. 1), dominantly composes typical meta sediments such as quartzite, marble, calc–silicate gneisses, garnet–sillimanite-bearing gneisses (khondalites) and psamo-pelites as interbedded lithologies intercalated with meta-igneous rocks such as amphibolites, charnockites and meta-gabbros. On the other hand in the WC, meta igneous rocks are dominant ranging from granitic, granodioritic to dioritic composition together with subordinate amounts of meta sediments such as quartzites[10]. The VC is dominated by granodioritic to dioritic and TTG gneisses with augen structures[10, 32, 35], with only scarce occurrences of quartzite and calc–silicate rocks close to its boundary with the HC (e.g.,[10, 12]). The doubly plunging synformal

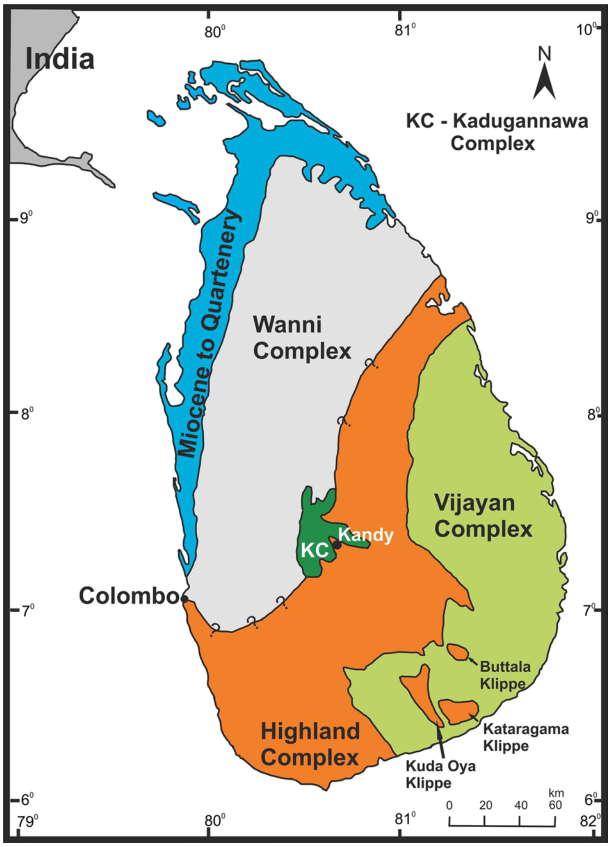

Figure 1: Proterozoic crustal units of Sri Lanka (after[10]).

structures of the KC contain mainly dioritic and granodioritic gneisses with migmatites and thin metasedimentary layers of quartzite, marble and calc–silicates[10,32].

1.1 Availability of U–Pb and Hf Isotope Data for Sri Lanka

Over the preiod of past 30 years, a significant number of research contributions were published relevant to the Sri Lankan Geology. Out of those, there are two main episodes in which a large number of papers published, could be identified: the first episode is early ninety's (from 1991 to 1994) and the second is the past 15 years (from 2003 to 2018). A detailed list of references which belong to the former episode could be found in Kröner and Williams[31], Milisenda et al.[43] and Cooray[10] The studies pertaining to the latter contributed to expanding the understanding of mainly zircon (and rarely monazite) U–Pb isotopic system and introducing Hf isotopic data of the Sri Lankan basement (e.g.,[20,21,28,34,35,39,45,49,54–57,63–65,70]. Hence, the main aim of this paper is to present a comprehensive review on U–Pb and Lu–Hf isotope systematics of metamorphosed magmatic rocks of the Sri Lankan Gondwana fragment. Summary of isotopic data available for Sri Lanka is presented in Table 1.

1.2 Metamorphism and Geochronology of Sri Lanka: An Overview

The metamorphism of the Sri Lankan basement is considered to be the result of micro-continental collisions associated with the formation of the Gondwana supercontinent (e.g.,[62]). The HC and WC show typical high-grade granulite facies metamorphism while the KC is characterized by upper amphibolite to granulite facies conditions. Although the VC is traditionally interpreted as a typical amphibolite facies terrain granulite facies rocks are also found in some localities[13,25,35,69]. In the HC rocks, metamorphic pressures and temperatures show a decrease from 8–9 kbar and 800–900 °C in the east and southeast to 4.5–6 kbar and 600–700 °C in the southwest[14,15,19,30,46,47,51,54,61,63,65]. The UHT metamorphic rocks are also exposed in this unit at several localities[15] and references therein;[46,47]. The estimated P–T conditions are $P=3.5$–7.5 kbar and $T=600$–900 °C[18,60] in the WC and KC. Predominantly, amphibolite facies assemblages are found in the VC, except for localized granulite facies assemblages (charnockites) in the eastern part[13,25,35,69].

The U–Pb data have provided a solid dataset for the age of metamorphism for HC, both WC and KC, and VC as 610–55^{0,} 590–540 and 510–460 Ma, respectively (e.g.[23,31,32,36]). In addition, Neoproterozoic growth of metamorphic zircons under ultrahigh temperature (UHT) metamorphic conditions has been firmly confirmed by recent studies from the HC[15,46,47].

Using Nd-model and U–Pb zircon ages a prolonged crustal residence has been inferred for the rocks of the HC, from ~ 3500 to 670 Ma (e.g.,[3,23,36,42,43]). Hence, the HC being the oldest terrain, represent Nd-model ages ranging from 3500 to 1850 Ma[42,43]. Nd-model ages of the WC range from 2000 to 1000 Ma, while that of the VC rocks vary in the range of 1900–1000 Ma[42,43]. The KC which structurally overlies the HC, represents Nd-model ages of 1850–1000 Ma[42,43].

Table 1: Summary of geochronology from Sri Lanka

	Residence age		Concordant/upper	Age of magmatism[b,c]				
	Nd-model age[a]	Hf-model age[b]	intercept age[c]	Mafic	Felisic-intermediate	Metamorphism[b,c]	eHf[b]	eNd[a]
Highland Complex	3500–1850 Ma	3580–1501	2700–1900	2010–521	1950–565	660–470	– 33.3 to 1.6	– 25 to (– 7)
Wanni Complex	2000–1000	2498–709	2745–750	1940–750	1860–546	660–480	4.4–13.1	– 8 to 4
Vijayan Complex	1900–1000	1600–625	1040–935	1040–537	1049–640	510–460	2–12	1.5–3.5
Kadugannawa Complex	1850–1000	2828–1031	1100–890	1100–890	1100–569	590–540	– 21.3 to 7.2	– 10 to 2

[a] Refs.[42,43]

[b] Refs.[20,35,57]

[c] Refs.[2,3,15,20,21,23,28,31,32,34,36,45,54–57,62–65,70]

2 Discussion

2.1 *Magmatism and Crust Formation in Sri Lanka: with Emphasis on Recent Findings*

The majority of previous U–Pb geochronological studies in early nineties (e.g.[32] and references therein) from Sri Lanka have incorporated conventional techniques for zircon dating including zircon evaporation thermal ionization mass spectrometry (TIMS). These techniques usually give a 'mixed' age, failing to obtain 'core-rim' ages, which is very critical in zircons of hig-grade metamorphic rocks. However, the subsequent studies have attempted SHRIMP/SIMS or LA–ICP–MS dating of zircons using U–Pb systematics at high-resolution recording individual growth zones or thermal events in zircons. Latest studies have incorporated Lu–Hf isotope systematics from insitu analysis of core-rim zones of zircons by ICPMS and have revealed much more insights into the tectonic evolution of the Sri Lankan Percambrian. In addition to U–Pb and Nd isotopes, Lu–Hf isotopic systamatics have also been applied to understand the magmatic and protolith characteristics of the Sri Lankan rocks (e.g.,[20, 21, 35, 57]). In the recent studies, metamorphosed rocks of dioritic, granodioritic, charnockitic, gabbroic and amphibolitic compositions have been analyzed to unravel tectonomagmatic history of the basement of Sri Lanka (e.g.,[20, 21, 35, 57, 63–65]). Malaviarachchi[38] elaborated implications on geochronology and tectonic significances of recent studies. The following is a brief overview summarizing age of magmatism and crust formation in Sri Lanka with a special perspective of U–Pb and Lu–Hf isotopic systematics.

2.1.1 Felsic-Intermediate Magmatism in Sri Lanka

In the HC, U–Pb detrital zircon ages from felsic gneisses range from 3200 to 2400 Ma and concordia upper intercept ages define an age group of 2100–1900 Ma (e.g.,[3, 23, 36, 42, 43]). Zircons from metamorphosed felsic to intermediate rocks of the HC record multiple late Neoproterozoic-Cambrian thermal events. Charnockites of the HC yield concordant multiple emplacement ages in the range of 565–1800 Ma and the metamorphic zircons show ages between 511 and 610 Ma[15, 20, 23, 28, 31, 32, 36, 57]. A single age of granitic magmatism at 670 Ma[3] has also been reported.

As for the WC, felsic gneisses record a time span of 1329–750 Ma as implied from detrital zircon U–Pb ages with concordia upper intercept ages of magmatic zircons ranging from 1100 to 750 Ma[23, 24, 33, 37, 42]. However, in the western part of the WC, intrusive alkaline granites record the latest magmatic activity as ~ 550 Ma[24, 50]. U–Pb zircon ages of charnockites from the WC characterize several age groups of which, the oldest upper intercept age is 1000 ± 52 Ma may represent the emplacement of the magmatic protolith[20, 28, 57]. The younger age groups corresponding to lower intercepts indicate Pb loss during multiple thermal events between the periods of 565–576 Ma, and closely identical to the Neoproterozoic magmatism of charnockites in the HC. The dioritic gneiss of the complex has upper intercept age of about 980 Ma. U–Pb concordant zircon ages of granodioritic gneiss of the WC show multiple thermal events at ages of 805 ± 12 Ma (emplacement of the magmatic protolith), 734.0 ± 4.6 Ma (Cryogenian thermal event) and 546.0 ± 5.7 Ma (latest Neoproterozoic–Cambrian metamorphism)[28, 57].

Zircons in granodioritic gneisses from the KC yield ages of 890 ± 16 to 1100 ± 57 Ma marking early Neoproterozoic magmatism followed by metamorphism at 532 ± 18 Ma, given by Concordia upper and lower intercepts, respectively[20, 57]. Charnockites of the KC yielded ages of 569 Ma and 958 Ma (concordia upper intercept), respectively as the emplacement age, while the concordant metamorphic age being 553 and 543 Ma[20], respectively. The incipient charnockites of the KC yields two concordant age groups of 784–661 and 850–970 Ma[20].

Granitic gneisses of VC record concordant U–Pb concordia upper intercept age from 1049 ± 2 to 935 Ma reflecting the time of emplacement of the protoliths[21, 35, 45]. A Tonian–Cryogenian age signal of ~ 820 to 640 Ma has been recorded from the rocks at the Highland–Vijayan tectonic mixed zone along the tectonic boundary[45].

2.1.2 Mafic Magmatism in Sri Lanka

Mafic magmatism is evidenced mainly by dioritic–gabbroic gneiss and amphibolites with minor pyroxenites in the Sri Lankan terrain. Zircons of the gabbroic gneiss of the HC yield several populations of zircon with weighted mean U–Pb ages in the range of 523–1950 Ma, while metamorphism is indicated by new zircon growth at 525 Ma defined by concordant grains[23, 24] and 921 Ma[15]. In the eastern part of the HC, zircons from garnet-bearing mafic granulite and clinopyroxenite show magmatic core ages in the range of 617–772 Ma, respectively[21]. The dioritic–gabbroic enclaves in the WC record multiple thermal events during 980–750 Ma[21]. As for the KC, U–Pb magmatic zircon concordia upper intercept ages vary in the range of 1100–890 Ma[20, 34, 57, 70], marking a minimum igneous crystallization age of 890 Ma (e.g.[36, 70]). Zircons in garnet–amphibolites and hornblende biotite gneiss yield emplacement age of 973 Ma defined by concordant zircons with extensive metamorphic recrystallization at 521 Ma[20]. In the VC, gabbroic gneisses records U–Pb Concordia upper intercept ages of ~ 1040 Ma[24, 35], whereas amphibolites record concordant U–Pb age of 537 Ma[35]. Zircons in mafic amphibolites and clinopyroxenites have recorded ages from 625 to 713 Ma[21].

2.2 εHf(t) Values and Model Ages of Sri Lankan Rocks

The zircon εHf(t) values in metamorphosed gabbroic rocks of the HC show a tight cluster from − 20.5 to 1.6 with crustal model ages in the range of 1501–2790 Ma[20, 57] suggesting a mixed source from both juvenile Neoproterozoic and reworked Mesoproterozoic–Neoarchean components (Fig. 2a). Zircons in charnockites also display predominantly large negative εHf(t) values from − 33.3 to − 6.7 and older crustal model ages from 2039 to 3580 Ma[20, 57] suggest involvement of reworked Paleoproterozoic–Archean crust in the genesis of magmatic rocks.

Zircons from charnockites of the WC possess all positive εHf(t) values ranging from 4.4 to 13.1 with crustal model ages in the range from 709 to 2498 Ma[20, 57] suggesting highly juvenile components in the magma source (Fig. 2b).

The Lu–Hf data reveal dominantly positive εHf(t) values for zircons of the KC in the metamorphosed rocks of dioritic and granodioritic composition from 0.4 to 7.2, with 1031 to 1662 Ma of crustal model ages (Fig. 2d). Amphibolites display εHf(t) from − 4.5 to 5.1 and Hf-crustal model ages of 1206–1733 Ma[20, 57] suggesting mixed sources from both juvenile and

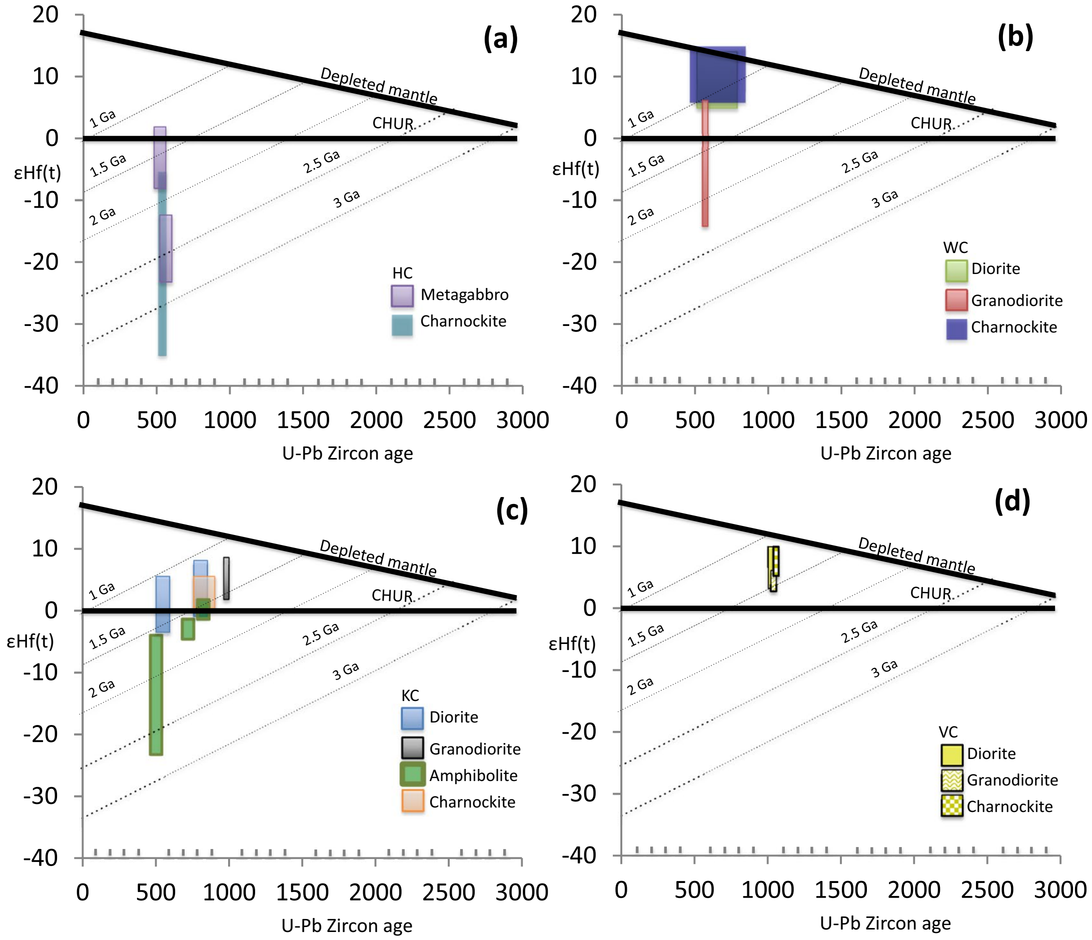

Figure 2: Epsilon Hf(t) values against U–Pb zircon ages of Sri Lankan lithotectonic units (**a** Highland Complex, **b** Wanni Complex, **c** Kadugannawa Complex, **d** Vijayan Complex) showing possible source characteristics.

Paleo-Mesoproterozoic components. However, zircons in garnet amphibolites from this complex show dominantly negative εHf(t) from − 21.3 to − 13.8 with crustal model ages in the range of 2356–2828 Ma[20, 57] suggesting reworked Paleoproterozoic–Archean crustal components in the magma source.

As for the VC complex, metadiorites display markedly positive εHf(t) values of 2.5–10 (Fig. 2d). Metagranodiorites show εHf(t) of 2–5.5, while charnockites have εHf(t) values of 4.5–10, inferring predominantly juvenile origins[35]. Hf-model ages are in the range of ~ 700–1600 Ma[21]. Garnet-bearing amphibolites and clinopyroxenites show dominantly positive εHf(t) (mean values of 12) with TDM in the range of 625–713 and 692–720 Ma suggesting juvenile-depleted mantle as the magma source[21].

In consideration of the Nd isotope data (e.g.,[35, 43, 70], the HC rocks show dominantly negative εNd(t) values from −7 to −25. Highly heterogeneous εNd(t) values of metamorphosed rocks of felsic and mafic composition are reported from −10 to + 2 and −8 to + 4, respectively, for the KC and WC and + 1.5 to 3.5 for the VC.

The distinct negative εHf(t) and εNd(t) values of the magmatic suites in the HC, with the Paleoproterozoic Hf crustal model ages suggest involvement of older recycled continental crustal components. The oldest Hf crustal model age of ~ 3.5 Ga is obtained from zircons in a garnetiferous charnockite from the HC of which zircon U–Pb age for crystallization is 1.8 Ga[57]. This is clearly consistent with melting of underlying older basement. Zircons in the metagabbro enclaves of charnockites in the HC[20] show negative to positive εHf(t) values, indicating the input of juvenile components into the HC crust, possibly at a subduction setting. Thus, the variable εHf(t) of zircon from negative to positive values with ages up to Palaeoproterozoic in the magmatic suite from Sri Lanka indicates the interactions of both juvenile mantle components and old continental materials in the generation of the arc-related magmatic suite. Accordingly, εHf(t) ranging from highly negative to positive values and model ages can be correlated with contribution of either older continental crust or subducting oceanic sediments, or both in the source region of the HC, mixed with mantle melts.

The markedly positive εHf(t) values of the WC (from + 5 to + 15) suggest depleted mantle source for magma origin in protoliths. In clear contrast, the εHf(t) values of samples from the KC are plotted close to the Chondrite line, ranging from slightly negative to positive, with crustal model ages mainly from 1.5 to 1.8 Ga (Fig. 2). This trend suggests that the protolith of the felsic rocks were derived from mantle sources with the input of minor crustal components within the arc setting. However, zircons in mafic rocks show dominantly negative εHf(t) values with Hf crustal ages of Paleoproterozoic implying reworked Neoarchean–Paleoproterozoic deep crustal magma sources. Thus, based on these signatures, the KC has unique petrological and Hf–Nd isotopic identities[20, 57] and hence it could be better interpreted not simply as a part of the WC (e.g.,[26, 34]), but as a marginal arc magmatic terrain that was exhumed and transposed along the margin of the WC[20, 57].

Clearly positive εHf(t)(t) data of the VC rocks support predominantly juvenile origin. Thus, crystallization of melts derived from the mantle at ca. 1000–1100 Ma could be suggested as the dominant crust-forming process in the Vijayan magmatic arc.

2.3 Geotectonic Models: From the Past to the Recent

Any tectonic model might not be able to sufficiently reproduce the near surface structural trends observed in the field terrain. However, in almost all collisional belts, the near surface structural patterns would be gently or nearly horizontal, whereas in the deep they become more and more vertical, and both sides of the orogene, they diverge opposite directions (e.g., [19, 40, 53, 58, 59]). Thus, foliations and/or stretching lineations measured by strike and dip cannot comprehend deep processes on a plate tectonic scale. Such trend lines reflect only the near surface dynamics although either seismic data on crustal and lithospheric scale or mineral fabrics in mantle rocks may help understanding deep structures. Hence, traces of the deep crustal or mantle dynamics directly evidenced from surface rock exposures could only be inferred from combined studies of petrology, geochemistry and spatial and temporal interrelationships of rock types.

In previous tectonic models, the WC is proposed to have collided with the HC and subsequently, both WC and HC together collided and thrusted over the VC[4, 66]. Pathirana[48] interpreted the HC–VC boundary as a subduction zone. Munasinghe and Dissanayake[44] and Dissanayake and Munasinghe[17] suggested the present HC as a sedimentary basin of a subduction zone where presence of siliceous and carbonate pelagic sediments in favour of forming quartzite–marble associations. They further suggested that the abundant and undisturbed development

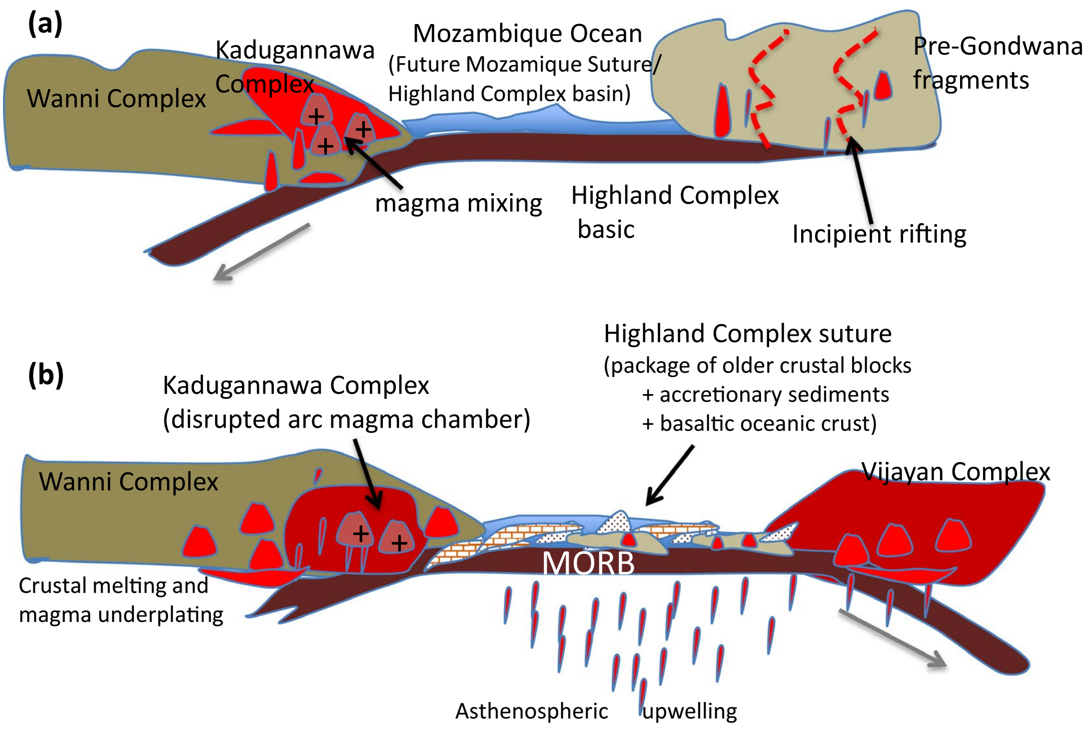

Figure 3: Paleoproterozoic 'two-staged subduction' in formation of the Sri Lankan tectonic terrains at active margin settings. **a** Rodinia dispersal and incipient rifting (~ 2000 to 1100). **b** Paleoproterozoic subduction around Sri Lanka during Gondwana amalgamation (~ 1100 to 700 Ma).

of the metasediments in the HC is indicative of a stable-shelf quiet water environment analogous to a present-day continental shelf zone[27, 29, 31–34, 67] speculated two major collisions for independently derived VC, WC and the HC. Further, Kröner et al.[34] and Willbold et al.[70] interpreted the VC is a part of Grenville-aged magmatic arc of unknown origin related to Rodinea breakup. Kehelpannala[27] used age interpretations of Hölzl et al.[23], Kröner et al.[34] and Willbold et al.[70] to speculate that the WC and VC magmatic arcs were brought together to subduct beneath HC microcontinent of unknown origin resulting two collisions within a very short time span from 550 to 580 Ma. Kröner et al.[35] considered the mantle-derived melts as the dominant crust-forming process in the Vijayan magmatic arc implying an intra-oceanic subduction zone. Thus, most of the above studies have concluded that the early Neoproterozoic magmatism in Sri Lanka is a result of passive continental margin tectonics representing the hallmarks of the breakup of the Rodinia supercontinent.

Nevertheless, Santosh et al.[57], He et al.[20, 21] and Takamura et al.[63, 65] showed that various Neoproterozoic magmatic pulses as described above in Sri Lanka clearly reflect geochemical evidence for active convergent margin setting at ca. 1000–1100 Ma. Further, accretion of oceanic components and arc magmatism reported by the latest studies using both age and geochemical data (e.g.,[20, 21, 57, 63–65]) support an active convergent margin setting. Moreover, extensive U–Pb and Hf isotopic data of Refs.[20, 35, 57, 63, 65] suggest that the WC and the VC were coeval (or at least near-coeval aged ~ 1 Ga) magmatic arcs formed during early Neoproterozoic at a double-subduction regime (e.g.,[20, 57]), whereas the Highland Complex is a marginal (paleo) ocean in the setting of Gondwana. Subsequently close to ~ 550 Ma, the WC and VC arcs have collided at late Neoproterozoic–Cambrian together with the accretionary sediments entrapped between the two arcs with the HC metamorphosing simultaneously (e.g.,[15, 20, 21, 57, 63–65]). This tectonic scenario probably appear to be more or less similar to the situation of Palghat Cauvery Shear Zone of southern India, which represents the Neoproterozoic closure of a part of the Mozambique ocean (e.g.,[41, 58]).

The broadly negative εNd(t) and εHf(t) values and older model ages are consistent with melting of underlying older basement rocks of Sri Lanka. The mafic to intermediate suites in the KC are explained as input of juvenile components stored in a large magma chamber at the supra-subduction setting of the WC in the Neoproterozoic, while the HC is a suture with oceanic and continental components, fragments of older continental crust and accretionary remnants of the subducting oceanic lithosphere with trench sediments found as MORB remnants (e.g.[57, 63–65]).

In view of the above age constraints, geochemical data and conceptual geotectonic models, it is apparent that the Highland Complex has been initiated to form as a part of the Mozambique Ocean. The WC was an arc formed at an active margin after Rodinea dispersal and the KC being a marginal arc magma entity (Fig. 3a). At a second stage, the WC–KC–HC entity may have subducted beneath pre-Gondwana continents forming the VC arc (Fig. 3b). Therefore, the double subduction envisaged in Sri Lanka could be further elaborated as a 'two-staged subduction' amalgamating the entire tectonic terrain of Sri Lanka. However, time lag between the first-stage subduction (i.e., WC) and the second-stage subduction (i.e., VC) might be several million years rather than being coeval, hence yet to be precisely determined.

3 Conclusions

The HC rocks preserve distinct imprints of reworking of older crust. Therefore, it is clear that the HC incorporates crustal components and material derived by melting of older (Paleoproterozoic to Archean) continental and oceanic components. The WC and KC represent arc magmatism during early Neoproterozoic, followed by continuous thermal events with significant melting of older crustal components of ages up to the Archean. Multiple thermal events during the Neoproterozoic in the VC characterize an ~ 1000 to 1100 Ma juvenile addition directly from the mantle. The latest Neoproterozoic to Cambrian high-grade metamorphism with approximate mean age of ~ 550 Ma have overprinted the previous magmatic events in all the basement rocks of Sri Lanka. All these signatures account for a two-staged subduction at active margin settings in amalgamating the four crustal units of Sri Lanka.

Acknowledgements

Two anonymous reviewers are thanked for constructive comments. Efficient editorial handling of Guest Editor M. Santosh is highly appreciated.

Received: 14 January 2018 Accepted: 10 April 2018

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