Proc Indian Natn Sci Acad **86** No. 1 March 2020 pp. 213-216

DOI: 10.16943/ptinsa/2020/49813

Status Report 2016-2019

The Himalayan Magmatic Events

SANDEEP SINGH[1], SANTOSH KUMAR[2], PIYUSH GUPTA[3], SAURABH SINGHAL[4] and ANAMIKA SAHU[1]
[1]*Department of Earth Sciences, Indian Institute of Technology Roorkee, Roorkee 247 667, India*
[2]*Department of Geology, Kumaun University, Nainital 263 002, Indiae*
[3]*Geochronology Laboratory, KDMIPE, ONGC, Kaulagarh Road, Dehradun 248 195, India*
[4]*Wadia Institute of Himalayan Geology, 33, Gen Mahadeo Singh Road, Dehradun, India*

(Received on 20 September 2019; Accepted on 29 September 2019)

This status report presents a brief account of magmatic events within the Himalayan domain; it includes all the relevant references which have been published after the year 2016 by Indian researchers. It is possible that some references might have been missed out which is entirely due to our ignorance and unintentional.

The Himalayas is the youngest and mightiest orogenic (a process in which a section of the earth's crust is folded and deformed by lateral compression to form a mountain range) belt in the world that has attracted the attention of all researchers worldwide on various aspects of the processes responsible for orogenic belt viz. sedimentation, magmatism, metamorphism, tectonics and the involvement of older Indian Plate components (Greater India). Orogenic belts are the terranes of compression, magmatism, topographic rise and erosion, deposition and metamorphism. For any orogenic belt, magmatism is one of the most important components of the tectonic expression of heat availability and its ability to melt partially the pre-existing rocks. Since 2016, several researchers have contributed to the aspect of magmatism of Himalaya from extreme NW to extreme NE.

Kumar *et al.* (2016 a, 2017) reported frequent occurrence of xenoliths of porphyritic andesite and dacite roof pendants within the Tirit granitoids (109-105 Ma, U-Pb zircon SHRIMP ages), Nubra valley of Trans-Himalaya. The sub-volcanic emplacement of Tiritgranitoid melt caused extensive assimilation and roof collapse of overlying volcanic materials. They also suggested the partial contribution of Proterozoic magmatic sources (713-952 Ma, 1933 Ma) and suggested that the Proterozoic component has contributed partly to the genesis of Early Cretaceous calc-alkaline magmatism forming the Tiritgranitoids.

Dhiman and Singh (2018, 2020) reported new U-Pb zircon ages by SHRIMP and LAMC-ICP-MS on Dalhousie and Dhauladhar granite, Himachal Himalaya. They indicated that the zircons reveal reworking of Neoproterozoic (magmatic core) during Cambro-Ordovician (magmatic rim) time and considered them as recycling of older crust during Neoproterozoic and Cambro-Ordovician time. They also tried to correlate Cambro-Ordovician continental magmatism building on the Greater Himalayan sequence and correlated with the amalgamation of Gondwanaland over the granite formed during Rodinian breakup at Neoproterozoic time. Dhiman and Singh (2019) carried out whole-rock geochemical analysis on samples from Dhauladhar and Dalhousie granites of the Himachal Himalaya and indicated them to be of peralumninous (S-type) nature. Granites are having sedimentary source with the psammitic nature for Dhauladhar and pelitic nature for Dalhousie granites. They also suggested that Dalhousie granites are more evolved than Dahuladhar granites. Similarly, Singh *et al.* (2016) looked at the mineralogical and geochemical features of felsic magmatic rocks of Kinnaur region and found them to be derived from

**Author for Correspondence: E-mail: sandpfes@iitr.ac.in; san662005@gmail.com, sandeep.singh@es.iitr.ac.in*

the melting of biotite-rich metapelites and metagraywacks.

Sen *et al.* (2018) recognize two major types of granite gneisses as upper (1895±22 Ma) and lower (1988±12 Ma) Bhatwari group gneisses in the Basal Part of Higher Himalayan Crystallines (HHC) along the Bhagirathi Valley, Garhwal Himalaya but they grouped them into Lesser Himalayan sequence. They reported that these granite gneisses are characterized as peraluminous (S-type) calc-alkaline magma generated from granite sources in volcanic-arc setting and metaluminous (I-type) alkaline melt formed by melting of a monzonite protolith in a rift environment, respectively. At the same time, Singh (2019) reported zircon growth in migmatites of the same Bhagirathi valley, exposed within the upper part of Higher Himalayan Crystallines (HHC) marking the exhumed high-grade mid-crustal material. The zircons from anatectic melt have multiple episodes between 46 and 20 Ma indicating protracted (i.e., >25 Ma) growth history of melt generation and correlated that with the evolution of orogen from the initial fluid-fluxed partial melting to post-collisional magmatic emplacement.

In a parallel valley towards east along Alakhnanda-Dahaliganga valley, Garhwal Himalaya, Mukherjee *et al.* (2019) reported U-Pb zircon age from deformed intrusive garnetiferous leucogranite around 480 Ma with older inherited Neoproterozoic cores. They also reported Paleoproterozoic Magmatic arc at the basal HHC i.e. Munsiari Group of rocks and demarcated Paleoproterozoic and Neoproterozoic terrane with distinct ε_{Nd} values and detrital magmatic zircon across Vaikrita Thrust within the Higher Himalayan Crystallines (HHC), which has earlier been designated as Basal HHC and Upper HHC.

As one moves further eastward, Mandal *et al.* (2016) reported ages from the Askot Klippe having 1857 ± 19 Ma granite-granodiorite gneiss, coeval with 1878 ± 19 Ma felsic volcanic rock, and circa 1800 Ma Berinag quartzite, representing a small vestige of a Paleoproterozoic (~1850Ma) continental arc, formed on northern margin of the northern Indian cratonic block. The U-Pb zircon chronology and Lu-Hf isotopic studies (*ca.* 1857 Ma, $\varepsilon Hf^{(t)} = -5.5$ to -1.2; *ca.* 1857-1878 Ma, $\varepsilon Hf^{(t)} = 9.6$ to 1.1) suggest that these granite gneisses were formed in a post-collision environment by melting of ancient continental sources with a small mafic magma input derived from juvenile source. Phukon *et al.* (2017) have also attempted zircon chronology on Munsiari augen gneisses (1970-1950 Ma) and Chiplakot granite gneisses (*ca.* 1920 Ma) and put forwarded an idea of about 100 Ma span of magmatism related to active subduction along the Proterozoic north Indian continental margin. This magmatism, however, represents calc-alkaline and shoshonitic compositions and reflects a signature representing the mixing of the mantle and crustal melts along with assimilation and fractional crystallization.

Das *et al.* (2018) tried to characterize geochemically the Ramgarh gneiss of Kumaun Lesser Himalaya and proposed that it may be a result of syn-collisional magmatism within Paleoproterozoic Columbia Supercontinent. They also proposed that subsequently during Cenozoic, these gneissic bodies exhumed as tectonic sliver and juxtaposed over younger Neoproterozoic Nagthat quartzites. However, Kumar *et al*. (2016) studied mafic dikes of tholeiitic affinity for paleomagnetic studies occurring in the Kumaun Lesser Himalaya within three tectonic segments and considered as Nainital, Almora and Pithoragarh dikes. The study indicated that only Pithoragarh dikes yielded palaeo-location (76.58^{o}N-336.2^{o}E) and suggested the emplacement age of *ca* 1000 Ma. This age most likely relates to the attenuation of Rodinia supercontinent to a maximum size at about 1000 Ma i.e. much later than the initiation of amalgamation at *ca*. 1300 Ma. Similarly, Srivastava and Samal (2019) analyzed mafic intrusive bodies from the Lesser and Higher Himalayas between Bomdila and Tawang in western Arunachal Pradesh. They concluded that the mafic magmatism is part of two distinct Paleoproterozoic mafic intrusive rocks occurring as small bodies of dikes, sills, and lenses. Bhattacharjee and Nandy (2017) reported the petrology and geochemistry of Western Arunanchal Pradesh, where they undertook Bomdila and Zimithang granite gneiss, Salari granite, and Higher Himalayan Leucogranite and correlated with four phases of magmatism.

Bikramaditya *et al.* (2018) reported peraluminous (S-type) to calc-alkaline metagranitoids of *ca.* 516-486 Ma from Subansiri in the eastern Himalaya, and have been interpreted their formation at the Indian passive margin by partial melting of major

Proterozoic metasedimentary (continental) sources (2.2 to 1.5 Ga) as evident from the observed negative εHf(t) values (–1.4 to –12.7) of zircons. Similarly, Pathak and Kumar (2019) carried out U-Pb zircon chronology on peraluminous (S-type) ms-bt granite gneiss from the Bomdila region (BGGn) of Kameng corridor, western Arunachal Himalaya and reported weighted $^{207}Pb/^{206}Pb$ mean age of 1752±23 Ma for zircon crystallization in BGGn. The observed negative $\varepsilon_{Hf}^{(t)}$ values (–1.67 to –7.99) and three-stage Hf-model ages (2818, 2586-2424 and 2393-2250 Ma) of zircons have been interpreted as the involvement of heterogeneous ancient continental crustal sources in the generation of BGGn melt. The reworked ancient crustal components would have once been part of the northern Indian lithosphere, as indicated by the observed $^{207}Pb/^{206}Pb$ concordant ages (*ca.* 2436, 2136, 2013 Ma) of the inherited zircons. Baral *et al.* (2019) reported the U–Pb ages of detrital magmatic zircons from the late Palaeocene to early Eocene Lower Yinkiong Formation, NE Himalaya which mostly cluster between Cambrian and Archaean, resembling cratonic and early Himalayan Thrust Belt affinity. Early to Mid-Eocene Upper Yinkiong Formation record Cenozoic magmatic zircons having Asian as well as Himalayan Thrust Belt resemblance. Based on these results, they further suggest that the India–Asia collision initially occurred during early Eocene (*ca.* 56 to 50 Ma) in the central Himalaya and further migrated towards east and west.

Acharyya *et al.* (2017) dated muscovite from pegmatites emplaced within the low grade Daling phyllite, Darjeeling-Sikkim Himalaya, and obtained ~1850 Ma Ar-Ar muscovite cooling plateau age, which is broadly coeval with the crystallization ages of Lingtse granite protoliths (e.g., 1800-1850 Ma, U-Pb zircon ages) from the lower part of Lesser Himalayan sequence. These plateau ages have been considered as crystallization ages of pegmatite.

Singh *et al.* (2019) presented a combined new geochemical and geochronological data to explain the tectonic evolution of the Abor Volcanics cropping out of the core of the Siang Window, Eastern Himalayan Syntaxis. On the basis of zircon U-Pb ages of three felsic volcanics, which is yielding ages between 130 to 133 Ma, and ε_{Hf} values of –7.0 to –13.3 and modal ages between 1.5 and 2.1 Ga, suggesting old crustal assimilation in their genesis. At the same time, REE geochemical data also suggest crustal contamination at the time of the eruption. This data along with Comei-Bunbury LIP of Southern Tibet and South-western Australia (~123-132 Ma) indicate that the Abor Volcanics were emplaced at early stage (~132 Ma) of eastern Gondwana breakup due to the outbreak of Kerguelen plume. They also emphasized the idea of Kerguelen plume affecting a large area of Eastern India, Western Australia, and Antarctica during early stage of Gondwana breakup.

Singh *et al.* (2017) reported for the first-time U-Pb zircon ages of 116 and 119 Ma from plagiogranites of Nagaland-Manipur ophiolites exposed in the Indo-Myanmar Orogenic Belt, NE India and correlated it with Neo-Tethyan ophiolites in the Indus-Yarlung-Tsangpo Suture. They also emphasized that geochemically these plagiogranites are part of the subduction zone magmatism having the source of depleted mantle.

References

Acharyya S K, Ghosh S, Mandal N, Bose B and Kanchan P (2017) Pre-Himalayan tectono-magmatic imprints in the Darjeeling-Sikkim Himalaya (DSH) constrained by 40Ar/39Ar dating of muscovite *J Asian Earth Sci* **146** 211-220

Baral U, Lin D, Goswami T K, Sarma M, Qasim M and Bezbaruah D (2019) Detrital zircon U–Pb geochronology of a Cenozoic foreland basin in Northeast India: Implications for zircon provenance during the collision of the Indian and Asian plates *Terra Nova* **31** 18-27

Bhattacharjee S and Nandy S (2017) Petrology and geochemistry of the Himalayan granites from Western Arunachal Pradesh, India *Indian Journal of Geosciences* **71** 439-448

Bikramaditya R K, Singh A K, Chung S-L, Sharma R and Lee H-Y (2018) Zircon U–Pb ages and Lu-Hf isotopes of metagranitoids from the Subansiri region, Eastern Himalaya: implications for crustal evolution along the northern Indian passive margin in the early Paleozoic. *Geological Society, London, Special Publications* **481** https://doi.org/10.1144/ SP481.7

Das A, Rawat P V S, Modak A and Nag R (2018) 1800 Ma Ramgarh Gneiss of Kumaun Lesser Himalaya – An example of Palaeoproterozoic magmatism in Columbia Supercontinent *Indian Journal of Geosciences* **72** 203-214

Dhiman R and Singh S (2018) Remelting of Neoproterozoic Dalhousie and Dhauladhar granite during Cambro-Ordovician: Constraints from in situ U-Pb zircon geochronology, Himachal Pradesh, NW Himalaya. Abstract volume of the 33rd Himalaya-Karakorum-Tibet Workshop, September 2018, Lausanne, Switzerland, 37, DOI: 10.5281/zenodo.1403887

Dhiman R and Singh S (2019) Petrogenesis and Geochemical Evolution of Dhauladhar and Dalhousie Granites, NW Himalayas *Journal Geological Society of India* **93** 399-408 DOI: 10.1007/s12594-019-1194-9

Dhiman R and Singh S (2020) Neoproterozoic and Cambro-Ordovician magmatism: episodic growth and reworking of continental crust, Himachal Himalaya, India *International Geology Review* DOI: 10.1080/00206814.2020.1716399

Kumar S, Bora S, Sharma U K, Yi K and Kim N (2017) Early Cretaceous subvolcanic calc-alkaline granitoid magmatism in the Nubra-Shyok valley of the Shyok Suture Zone, Ladakh Himalaya, India: Evidence from geochemistry and U–Pb SHRIMP zircon geochronology, *Lithos* **277** 33-50 https://doi.org/10.1016/j.lithos.2016.11.019

Kumar S, Bora S and Sharma U K (2016 a) Geological appraisal of Ladakh and Tiritgranitoids in the Indus-Shyok Suture Zones of Northwest Himalaya, India *Journal of Geological Society of India* **87** 737-746

Kumar S, Singh N S and Patil S K (2016 b) Mineralogy, Geochemistry and Palaeomagnetism of mafic dykes from Kumaun Lesser Himalaya: Implication on Petrogenesis, Tectonic Setting and timing of mafic magmatism in northern part of Indian Lithosphere *Acta Geol Sinica* **90** 120-121

Mandal S, Robinson D M, Kohn M J, Khanal Das O and Bose S (2016) Zircon U-Pb ages and Hf isotopes of the Askotklippe, Kumaun, northwest India: Implications for Paleoproterozoic tectonics, basin evolution and associated metallogeny of the northern Indian cratonic margin *Tectonics* **35** 965-982 doi:10.1002/2015TC004064

Mukherjee P K, Jain A K, Singha N B, Singh S, Kumud K, Seth P and Patel R C (2019) U-Pb zircon ages and Sm-Nd isotopic characteristics of the Lesser and Great Himalayan sequences, Uttarakhand Himalaya, and their regional tectonic implications *Gondwana Research* **75** 282-297 https://doi.org/10.1016/j.gr.2019.06.001

Pathak M and Kumar S (2019) Petrology, geochemistry and zircon U–Pb–Lu–Hf isotopes of Paleoproterozoic granite gneiss from Bomdila in the western Arunachal Himalaya, NE India *Geological Society, London, Special Publications* **481** https://doi.org/10.1144/ SP481-2017-169

Phukon P, Sen K, Srivastava H B, Singhal S and Sen A (2017) U-Pb geochronology and geochemistry from the Kumaun Himalaya, NW India, reveal Paleoproterozoic arc magmatism related to formation of the Columbia supercontinent *Geological Society of America Bulletine* **130** 1164-1176.https://doi. org/10.1130/B31866.1

Sen A, Sen K, Srivastava H B, Singhal S and Phukon P (2018) Age and geochemistry of the Paleoproterozoic Bhatwari Gneiss of Garhwal Lesser Himalaya, NW India: implications for the pre-Himalayan magmatic history of the Lesser Himalayan basement rocks *Geological Society, London, Special Publications* **481** doi: https://doi.org/10.1144/ SP481.6

Singh A K, Chung S-L, Bikramaditya R K and Lee H Y (2017) New U-Pb zircon ages of plagiogranites from the Nagaland-Manipur ophiolites, Indo-Myanmar Orogenic Belt, NE India *Journal of Geological Society London* **174** 170-179. Doi: 10.1144/jgs2016-048

Singh A K, Chung S L, Bikramaditya R K, Lee H Y and Khogenkumar S (2019) Zircon U–Pb geochronology, Hf isotopic compositions, and petrogenetic study of Abor volcanic rocks of Eastern Himalayan Syntaxis, Northeast India: Implications for eruption during breakup of Eastern Gondwana *Geological Journal* 1-18. https://doi.org/ 10.1002/gj.3477

Singh B, Kumar S, Ban M and Nakashima K (2016) Mineralogy and geochemistry of granitoids from Kinnaur region, Himachal Higher Himalaya, India: Implication on the nature of felsic magmatism in the collision tectonics *Journal of Earth System Science* 125 1329-1352 https://doi.org/ 10.1007/s12040-016-0748-0

Singh S (2019) Protracted zircon growth in migmatites and In situ melt of Higher Himalayan Crystallines: U–Pb ages from Bhagirathi valley, NW Himalaya, India *Geoscience Frontiers* **10** 793-809. https://doi.org/10.1016/ j.gsf.2017.12.014

Srivastava R K and Samal A K (2019) Geochemical characterization, petrogenesis, and emplacement tectonics of Paleoproterozoic high Ti and low Ti mafic intrusive rocks from the western Arunachal Himalaya, northeastern India and their possible relation to the ~1.9 Ga LIP event of the Indian shield *Geological Journal* **54** 245-265 https:/ /doi.org/10.1002/gj.3172.