STUDY OF PERMO-CARBONIFEROUS PALEOCLIMATIC EVENT IN EASTERN HIMALAYA

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ABSTRACT

The history of Late Paleozoic cryospheric event of Permo-Carboniferous Period is widely spread and preserved globally in the form of sedimentary facies. The Permo-Carboniferous sedimentary sequences of Peninsular India have been well studied and categorized mainly into three major basins, i.e., Son-Mahanadi basin, Pranhita-Godavari basin and Damodar basin. Their equivalent sedimentary sequences from the Permo-Carboniferous were also deposited simultaneously, around the northern margin of peninsular India which is also known as peri-Gondwana sequences. These peri-Gondwana sequences are well preserved and exposed in the Himalaya i.e., Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh. The sedimentary sequences of Sikkim-Darjeeling Himalaya have witnessed a wide span of climate change during the Permo-Carboniferous period. The signatures of Permo-Carboniferous glacial and interglacial events are recorded in the form of sedimentary facies in two different basins, Rangit Pebble Slate Formation in the Lesser and Lachi Formation in the Tethyan Sikkim Himalaya.

Integrated lithological, petrological, and geochemical approaches were used for evaluation of the Rangit Pebble Slate and Lachi Formation of Sikkim Himalaya. The geochemistry and petrography have been done with an aim to establish provenance, tectonic setting and weathering intensity for the sediment of the Rangit Pebble Slate (RPS) and Lachi Formation. The lithological association of these peri-Gondwana sequences from Sikkim Himalaya includes the diamictite facies at the base and the alternating sandstone-shale facies at the top of the sequence. Lowermost sequences of both the formations are characteristically recognized by boulder beds and diamictite facies which suggests a glacial environment of deposition, while the upper sequences of alternate sandstone and shale are considered marine transgression. The lenticular bedding with continuous thick lenses in the uppermost sequence of Rangit Pebble Slate Formation shows the evidence of

tidal wave. The whole lithofacies sequence shows a series of fining-upwards cycles which might be due to transgression of Tethys Sea after the Permian glaciation event. The stratigraphic sequences of Rangit Pebble Slate and Lachi Formation indicate a transgressive tract system. The presence of marine fossils like *Eurydesma* also confirm the marine environment of deposition.

The ternary and diamond diagram for the composition of sandstone indicate that sediments of Rangit Pebble Slate and Lachi Formation are dominant with monocrystalline quartz, feldspar, rock fragments and are classified as sub-arkose and arkosic arenites. Both coarse and fine-grained sandstones from the study area were evaluated and it was observed that these sediments were derived from plutonic and high-grade metamorphic terrain. The ternary plot of provenance and tectonic setting clearly suggests that the sediments of the Rangit Pebble Slate and Lachi Formation were derived from stable cratonic and interior continental areas which were originally deposited in passive continental margins.

The Harker's variation diagram shows the dominance of SiO_2 against various other oxides in all studied samples. The plot of major elements K_2O vs. Na_2O quantifies the richness of quartz in all studied samples indicating that these sediments were derived from quartz-rich provenance. The tectonic discrimination diagram between K_2O/Na_2O Vs SiO_2 infers the area of a passive margin. The enrichment of SiO_2, Al_2O_3, TiO_2, MnO, MgO, and K_2O indicates that these sediments were mostly derived from felsic rock source areas. The chondrite normalized REE pattern with high value of LREE/HREE ratio with Eu negative anomalies also indicate that sediments of Rangit Pebble Slate and Lachi Formation were derived from felsic sources. The values of Chemical Index of Alteration (CIA) suggest the cold environment of deposition for the sediments of lower sequences whereas the deposition of sediments of upper sequences was warm and humid. The A-CN-K ternary plot also indicate that the source areas were subjected to prolonged intense chemical

weathering from low to high grade due to shifting of cold to warm humid paleo-climatic condition.

The petrological and geochemical analysis of all studied samples of Rangit Pebble Slate and Lachi Formation shows close affinities with other peninsular Gondwana basins in terms of tectonic setting and provenance, i.e., passive tectonic setting and granitic source. Most of the studied samples of both the formations were plotted in the plutonic fields which indicate the granitic source of rock which might have been derived from the stable plutonic craton of Peninsular India i.e., Chtonagpur Granite Gneiss Complex (CGGC), Shillong Plateau Gneissic Complex, Proterozoic sedimentary rocks, etc. The Chotanagpur Granite Gneiss Complex (CGGC) and Shillong Plateau Gneissic Complex of the Indian shield lying to the southwestern of Sikkim-Darjeeling Gondwana basin, which is composed of high-grade migmatitic gneiss, khondalite, quartzite, and basic igneous rock. The other Permo-Carboniferous sedimentary sequences of Himalaya i.e., Arunachal Pradesh and Spiti region of Himachal Pradesh have shown close similarity in terms of provenance tectonic setting and climatic condition.

The present study of Permo-Carboniferous sedimentary sequences of Sikkim-Darjeeling Himalaya (i.e., Rangit Pebble Slate Formation and Lachi Formation) deciphers its provenance, paleo-environment, tectonic setting, and paleo-weathering conditions. The provenance and tectonic setting of the Rangit Pebble Slate Formation (RPS Fm.) and Lachi Formation have been established through lithostratigraphy, petrography, and geochemical (major, traces and REE) studies. The lithostratigraphic sequence of both formations strongly suggests glacio-marine sedimentation for its sedimentary facies. The cryogenic / glaciogenic event is represented by diamictite facies at the base to the fine sandstone-shale sequence, followed by shallow marine deposition at the top of the sequence. The fine clastic facies association of alternate sandstone and shale directly overlies the thin bedded glacial diamictite characterized by sedimentation in glacio-marine environment. The glacial-postglacial sedimentary facies exhibit a clear fining upward sequence during the marine transgression (Amon, 1997). The architecture facies of Rangit Pebble Slate Formation and Lachi Formation exhibits the same pattern of sedimentation which indicates the influence of both glacial and marine environment. Further, the record of typical marine invertebrates and ichno-fossils in the bed of Permo-Carboniferous sedimentary sequence of Gondwana Basin of Peninsular India and Himalayan Gondwana basin shows close affinities and suggests the identical environment of deposition.

The petrographic studies through different plot (i.e., QFL plot, Qp-Lv-Ls plot) and binary plot of all major oxides of Rangit Pebble Slate and Lachi Formation have shown the dominance of silica (SiO_2). Both petrography and geochemistry suggest the same felsic source which could have been derived from plutonic igneous rock as well as high grade metamorphic rocks. The REE pattern with a negative Eu anomaly and elemental

ratios of traces elements of Rangit Pebble Slate Formation and Lachi Formation sandstone also strongly support that these sediments are enriched with felsic source rock and closely associated with upper continental crust (UCC). The sediments of Rangit Pebble Slate Formation and Lachi Formation may have been derived from Proterozoic Himalayan granites and gneisses and quartzose sedimentary rock which were accumulated in a basin may be due to tectonic upliftment of the sedimentary basin in the early Paleozoic in a humid to semi humid climatic condition (Srikantia and Bhargava, 1998; Myrow et al., 2006; 2010; Garzanti et al., 2007; Jain et al., 1981; Kumar et al., 2020). The trend of Chemical Index of Alteration (CIA) and A-CN-K ternary plot throughout the stratigraphic section (upper and lower strata) indicates a shift from cold to warm humid climate. The combined study of both CIA and A-CN-K plot of Rangit Pebble Slate and Lachi Formation diamictite and sandstone indicates low to moderate chemical weathering due to variation in paleoclimatic conditions after post glaciations. Considering the integrated approach of both lithostratigraphy and geochemistry, the source of Rangit Pebble Slate and Lachi Formation might be assigned to Indian Shield (i.e., Chhotanagpur Granite Gneiss Complex, Shillong Plateau Gneissic Complex) including Proterozoic Himalayan crystalline gneiss under humid to semi-humid climatic condition. The proposed model, on the basis of lithofacies, petrography and geochemistry for Rangit Gondwana Basin of Sikkim and its associated basin of Darjeeling, had a passive foreland setting and the northern parts were opened into Paleo-Tethys Sea. The other Himalayan Gondwana basin (Western and Eastern) of India shows the similar pattern of sedimentation and tectonic environment.

An integrated study of lithostratigraphy, petrography and geochemistry, the following conclusions have been drawn based on the detailed field and laboratory investigations and results obtained from various studies.

- The lithostratigraphic sequence of the Rangit Pebble Slate and Lachi Formation strongly suggests glacio-marine sedimentation for its sedimentary facies. The cryogenic / glaciogenic event is represented by diamictite facies at the base of the fine sandstone-shale sequence and shallow marine deposition at the top of the sequence.
- Both petrography and geochemistry suggesting the same felsic source which could be derived from plutonic igneous rock as well as high grade metamorphic rocks.
- The REE pattern with a negative Eu anomaly and elemental ratios of trace elements of Rangit Pebble Slate and Lachi Formation sandstone strongly support that these sediments are enriched with felsic source rock and closely associated with upper continental crust (UCC).
- The lower unit of Rangit Pebble Slate and Lachi Formation comprise of Diamictite-Conglomerate-Sandstone facies represent Cryogenian event (Late Paleozoic glaciation). It is also supported by the CIA and A-CN-K plot indicating low to moderate chemical weathering due to cold paleo climatic condition.
- The Himalayan peri-Gondwana sedimentary sequences of Sikkim-Darjeeling Himalaya were deposited along the northern Passive margin of India during Permo-Carboniferous period.
- The sources of sediments (Provenance) for Rangit Pebble Slate and Lachi Formation have suggested that these sediments were derived from Archean and Proterozoic Indian shield i.e., Chtonagpur Granite Gneiss Complex (CGGC),

Shillong Plateau Gneissic Complex (SPGC), Proterozoic Himalayan granite-gneisses and quartzose-dolomitic sedimentary rock.

- The litho-stratigraphic and paleontological correlation based on marine and non-marine fossils, with other Permo-Carboniferous successions of Eastern and Western Himalaya, in India (e.g., Kashmir, Himachal Pradesh, and Arunachal Pradesh) strongly suggests a remarkably close similarity in provenance, tectonic setting and paleo-climatic conditions.
- The diamictite-conglomerate facies and the sedimentary structures viz. dropstones, tidal rhythmites sandstone, lenticular bedding with marine fossils clearly indicates a glacio-marine environment of deposition for Rangit Pebble Slate Formation in Lesser Himalaya, South Sikkim and Lachi Formation, Tethys Himalaya in North Sikkim.
- The Peri-Gondwana basins of the Sikkim Himalaya (Rangit Pebble Slate Formation and Lachi Formation) shows similarity with Peninsular Gondwana basins of India (Talchir Formation) in their sedimentary processes, paleo-environment, and paleo-glaciation.

Present study of Peri-Gondwana basins of Sikkim – Darjeeling Himalaya has helped in reconstructions of the paleogeographic map of Late Paleozoic Period in general and Permo – Carboniferous glaciations in Gondwanaland paleo-Tethys realm.