that occurred in the area during 7000–6000 yrs BP, engulfed the land up to 8 km west of present Poompuhar-D and the sea had withdrawn to present Poompuhar-D region only around 2500–2000 yrs BP according to the ^{14}C dating of beach ridges of Vedaranniyam area[18]. Probably, Poompuhar-D (Kaveripoompattinam) might have flourished more during the Sangam period and hence glorified the Sangam literature. So what is mentioned in the Sangam literature about Poompuhar is only about Kaveripoompattinam. No tools and technologies were available in the past for 3D mapping of sea-bed topography, visualization of different scenarios of sea-level rise and the mapping of past coastlines. Hence, the earlier workers could not visualize the possibility of Poompuhar inside the sea and obviously the question of archaeological remains/^{14}C dating in Deltas A and B did not arise.

Thus existence of arcuate/lobate deltas of the Cauvery inside the sea in the above-mentioned locations and the obvious postulations of earlier Poompuhar cities in those deltas cannot be ignored. However, these new scientific postulations on the possibility of Poompuhar city in Delta-A and Delta-B regions (Figure 3) warrant detailed studies.

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Received 5 March 2016; revised accepted 16 December 2016

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Incidence of gold associated with copper mineralization in Garhwal Lesser Himalaya, Rudraprayag district, Uttarakhand, India

Base-metal mineralization occurs widely in the rocks of the Garhwal Group of Proterozoic Lesser Himalayan Sequence, viz. Dhanpur, Pokhri and Mohankhal prospects, but gold (Au) associated with such mineralization is rarely recorded from Garhwal Himalaya. Here we report significant incidences of gold associated with sulphide mineralization in dolomite-hosted quartz–carbonate veins of Pithoragarh (=Lameri) Formation from Lameri–Koteshwar area, in parts of Rudraprayag district, Uttarakhand, India. The Au values recorded from bedrock and stream sediment samples from the area are 475 ppb and 1.42 ppm respectively. Scanning Electron Microscope – Energy Dispersive X-ray (SEM-EDX) studies have indicated the presence of gold along with chalcopyrite, pyrite, sphalerite and galena in various samples. The identification of native gold in quartz vein, under SEM, is the first record of *in situ* gold incidence from Rudraprayag area. Sporadic occurrences and small deposits of metallic minerals in the Garhwal belt are mainly restricted to Mesoproterozoic to Early Palaeozoic.

The studied area falls under Survey of India toposheet nos 53 J/15 and 53 N/3 in parts of Rudraprayag district. The regional geology comprises volcano-sedimentary sequence of Meso–Proterozoic Garhwal Group, which is subdivided into four formations in stratigraphic sequence in ascending order namely Agastmuni, Rautgara, Pithoragarh (=Lameri) and Berinag (=Nagnithank)[1] (Figure 1). This part of the Lesser Himalayan sequences is sandwiched by the Main Central Thrust in the north and North Almora Thrust in the south. The study area comprises rocks of Rautgara, Pithoragarh and Berinag formations intruded by mafic dykes (meta-gabbro). Dolomite of Pithoragarh/Lameri Formation is dominantly exposed in Lameri–Koteshwar area with occasional bands of carbonaceous slate. The dolomite is stromatolitic, light grey in colour and is intruded by thin quartz–carbonate veins. These quartz–carbonate veins are usually diffused within dolomite and such zones of dolomite-hosted veins vary in their width from a few centimetres to as much as 8 m. Chlorite schist associated with quartzite of Berinag Formation occurs dominantly to the west of the area and is best exposed around Rudraprayag town in the Mandakini River valley (P. S.

Misra *et al.*, unpublished report, Geological Survey of India, 2012).

Surface indications of sulphide mineralization are noticed as profuse development of malachite and azurite stains. In Lameri area, specks of pyrite are concentrated in the quartz–carbonate veins and brown iron-oxide patches hosted by milky-white crypto-crystalline quartz veins within dolomite. Another set of pinkish-brown brecciated quartz veins (20–50 cm wide extending up to 5 m) with dolomite clasts has sulphide disseminations, mainly chalcopyrite with subordinate pyrite around the clasts. On the other hand, in Koteshwar area, dissemination of chalcopyrite specks with chunks of pyrite is common with profuse malachite stains. Several small, old workings are recorded from Lameri–Koteshwar area. A cluster of five old workings is observed in Lameri area. Old workings are in the form of shallow pockets and one incline having malachite-stained quartz vein. Brownish-grey slag was observed as dump near the old working site and one retort piece has also been recorded. Around Koteshwar area, a cluster of five old workings has been identified in dolomite with malachite-stained quartz veins having disseminated pyrite and chalcopyrite specks with occasional galena and bornite. In Lameri area, two small copper mineralized zones, viz. Zone I: Cu 0.51% × 6 m and over a strike of 20 m, and zone II: Cu 0.25% × 6 m and over a strike of 10 m were delineated based on channel sampling. The samples from old working zone in Lameri area have shown values up to 0.50% Cu, while those from Kimotha area have yielded 0.10–0.73% Cu. From Koteshwar–Machendranath area, average Cu value was 0.19% with some significant spot values of 0.39% and 1.64% Cu.

Analytical results of 355 samples indicate that the higher values of gold are associated with the concentration of sulphides. The gold and base metals were analysed by AAS method at the Chemical Division of Geological Survey of India (GSI), Lucknow. The samples were collected from mineralized locales of Lameri–Koteshwar area. Gold values in dolomite-hosted quartz veins range from <3 ppb to as much as 475 ppb. The control of these quartz veins is essentially structural in nature, and quartz veins are oriented in both NE–SW and NW–SE trends. The highest value of 475 ppb Au is obtained from a NW–SE trending quartz vein emplaced along axial planar fractures of F_2 folding event.

Stream sediment sampling was also done at various locations, particularly in the tribituary nalas and rivers. Stream sediment samples collected from Ratura, Sumerpur area yielded Au values from 200 to 300 ppb, with spot high values of 980 ppb and 1.42 ppm Au from the right bank of Alaknanda river (Ratura–Dharkot area). Heavy panned residues of samples from Ratura, Sumerpur area yielded 5–80 ppm Au. Panning of stream sediments revealed a few visible gold flakes from the panned residue of stream sediment of Alaknanda and Mandakini rivers in Sumerpur–Ratura, Sari and Jugtoli areas respectively (Figure 2 *b*). These gold flakes were confirmed through SEM-EDX studies (Figure 2 *a*).

SEM-EDX studies were carried out at GSI, Lucknow for a few rock chip samples from the study area. A sample of quartz vein within dolomite from Koteshwar area shows an assemblage of sulphides within silicate gangue. Dominant sulphides are pyrite and chalcopyrite with galena as accessory. Pyrite and chalcopyrite occur as dissemination and are seen to be present essentially along the fractures. A native gold grain is observed in this sample under SEM. Figure 2 *c* and *d* shows the EDX spectrum and back-scattered electron image of the analysed gold grain.

Disseminated gold grains (under SEM-EDX) have been reported from Bhowali metabasalt of Bhimtal Formation, Kumaon Himalaya[2]. The presence of disseminated gold in metabasalt is suggested due to widespread hydrothermal activity which caused precipitation of gold after the rocks had witnessed peak metamorphism[2]. Presence of auriferous sulphide veins at Kimkhet and sulphidic hydrothermal breccias has been documented from Kumaon Himalaya (M. Prasad *et al.*, unpublished report, Geological Survey of India, 1994).

Proterozoic plume-related activities were recorded in the Garhwal Group and manifested in the form of meta-gabbroic intrusives and meta-volcanics[3]. It appears that the present mineralization is due to the overprinting of mineralizing events which may be related to intrusive activities of metabasic and acidic phases. Such igneous activities are favourable for copper sulphide associated with gold mineralization[4]. Au values are also obtained from other lithologies, although much lower than those in dolomite-hosted quartz veins of Lameri–Koteshwar area, viz. meta-gabbro (62 ppb),

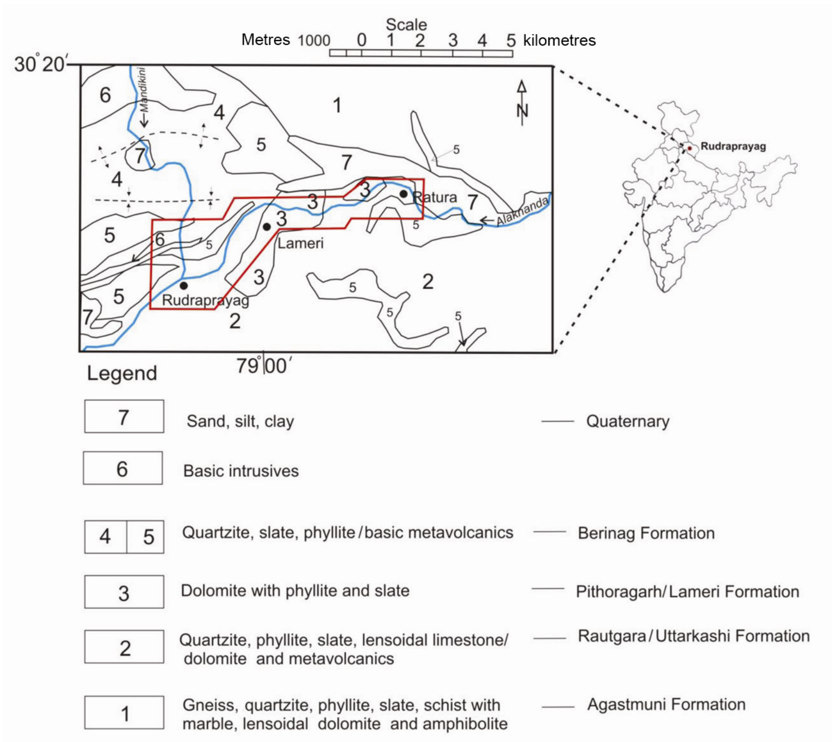

Figure 1. Regional geological map showing the investigated Lameri–Ratura area.

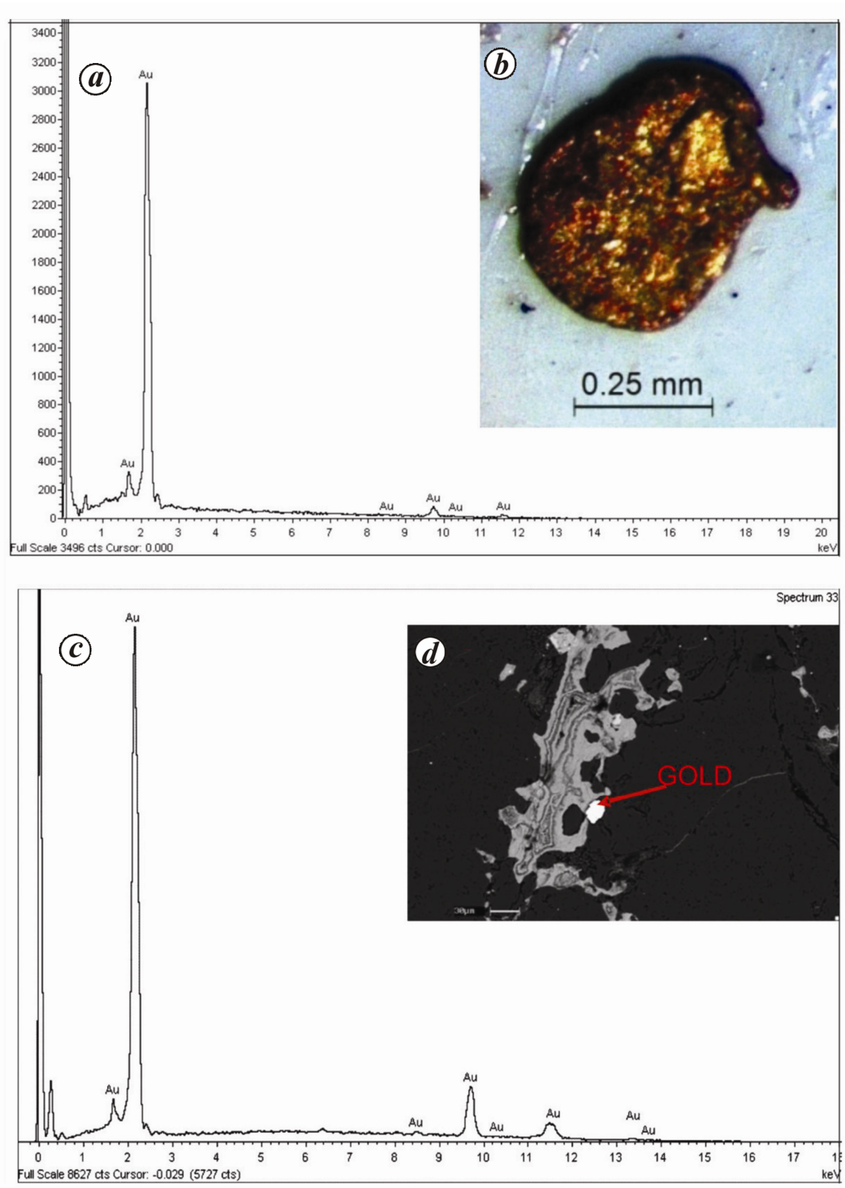

Figure 2. ***a***, Energy dispersive X-ray (EDX) spectrum of gold grain from Ratura–Sumerpur area. ***b***, Photograph of the same sample. ***c***, EDX spectrum of gold in quartz vein from Lameri–Koteshwar area. ***d***, BSE image of the same sample.

carbonaceous slate (66 ppb), dolomite (110 ppb) and chlorite schist (124 ppb). Analysis of a sample of slag near the old working has yielded Au value of 45 ppb. Gold may occur as coarse, liberated particles and fine particles locked in pyrite and copper sulphide[5]. Fractures are ideal locales for mineralization and hydrothermal activity to concentrate, in large proportions, the elements otherwise present in traces in the country rock[4]. Such brittle fractures developed during the Himalayan orogeny may have played a major role in acting as conduits for hydrothermal solutions. Low sulphide-associated auriferous quartz vein of Lameri–Koteshwar area is one such example. The ore fluid convection occurred in the structurally weak planes, fault zones and subsidiary fractures, ore fluid circulation in dilational structures with the presence of reactive carbonate-bearing rock-focused ore deposition. The discontinuous mineralized lenses are replacement or cavity-filling-type along joints or fractures, and suggest epigenetic hydrothermal origin. The occurrence of placer gold around Rudraprayag is indicative of some probable potential auriferous zone towards the northern part of the region comprising volcano metasedimentary sequence of Lesser Himalaya or the Central Crystalline of Higher Himalayan sequence of Garhwal Himalaya.

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ACKNOWLEDGEMENTS. We thank Shri S. P. Nim (ADC, Geological Survey of India, Northern Region, Lucknow) for encouragement and permission to publish this paper. We also thank the reviewer for useful suggestions that helped improve manuscript.

Received 22 November 2016; revised accepted 23 January 2017

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