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Environmental magnetic studies of soil profiles from tropical Southern India: A window to pedogenic processes and sediment-source linkage

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Of the several approaches adopted to study pedogenic processes, the environmental magnetic one is ideally suited to study the formation, dissolution and transformation of Fe-bearing minerals in soils. This approach is simple, rapid, non-destructive and sensitive. Most such studies have focused on temperate soils; only limited studies are available on tropical soils [for example, 1, 2, 3]. This paper is an attempt to document pedogenic processes in three soil profiles from a lake catchment in Southern India and to evaluate sediment-source linkage for possible use in lake sediment magnetic studies for paleoclimatic reconstruction.

We sub-sampled (at intervals of 2 to 10 cm) three soil profiles (HK-I, HK-II and MG) from the catchment of Hirekolale lake (13°21’34’’ N; 75°42’30’’ E), Chikkamagalur District, Karnataka, Southern India. Parent rock is granitic gneiss, schist and banded iron formations (BIF’s). The annual average rainfall is 1925 mm that is received mainly during the SW (= Indian = summer) monsoon. Magnetic susceptibility (χlf), frequency-dependant susceptibility (χfd) and sand, silt and clay percentages were determined using standard procedures.

The down-profile variations of magnetic parameters demarcate three zones, with the top and bottom zones exhibiting higher values compared to the middle one in all the profiles. The top 10 cm in HK-1 and MG exhibit very high values of χlf (17.86 to 154.03 x 10^{-8} m^3 $kg^{-1}$and 509.08 to 1599.48 x 10^{-8} m^3 kg^{-1}) and χfd (1.24 to 19.244 x 10^{-8} m^3 kg^{-1} and 57.43 to 122.74 x 10^{-8} m^3 kg^{-1}), suggesting magnetic enhancement. This results from the neoformation of superparamagnetic pedogenic magnetite when ferrous ions liberated from chemical weathering are oxidised under suitable Eh-pH conditions. Magnetic enhancement is well documented in many temperate soils [4] but not in soils from tropical Southern India. The top 25 cm in HK-II profile also exhibits magnetic enhancement (χlf = 36.76 to 72.92 x $10^{-8}m^3kg^{-1}$; χfd = 2.54 to 6.33 x $10^{-8}m^3kg^{-1}$) but with intermittent low values of both parameters, possibly due to top-soil erosion and / or illuviation. The middle zone of all the profiles shows low values of magnetic parameters, suggesting eluviation. The bottom zone of all the profiles is characterised by high χlf values and significant χfd % (5.16 to 10.89 %, 2.86 to 11.36 % and 6.20 to 8.91 %), suggesting that pedogenic magnetite production extended to the bottom zone as well because of the prevailing tropical climatic conditions. Alternatively, the high values may have resulted from illuviation. Values of χlf are generally high in MG compared to HK-I and HK-II as the former is hosted by BIF’s. However, the χfd% values are comparable (6.209 to 11.282 %, 2.857 to 12.307 % and 4.347 to 12.903 %). This shows that irrespective of parent rock lithology, χfd can be gainfully utilised for paleoclimate reconstruction. Magnetic minerals are present in the silt fraction of soils.

The documentation of magnetic enhancement in the soil profiles is significant; after the climate signal is carried and deposited in Hirekolale, a small lake nearby, it may be deciphered through environmental magnetic studies of lake sediment samples. Thus, a sediment-source linkage is established which would add strength to interpretation of lake sediment magnetic data from Hirekolale (see abstract by Shetty et al., 2016; this volume).

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