ABSTRACT

Weathering and erosion are major geological processes affecting the shape of the land surface, the development of soils and the chemical composition of natural waters. Chemical weathering of rocks and minerals is an integral part of the process by which elements are fractionated at the Earth’s surface by mineral dissolution reactions taking place at the mineral-water interface. The chemical reactions that govern the conversion of bedrock minerals into soil minerals predict the release of dissolved constituents to the waters. By this mechanism, base cations, silica and other essential nutrients are made available to biological systems, therefore, determine the fertility status of the region. This study presents field evidence, mineralogical observations and geochemical data of several weathering profiles developed over a variety of bedrocks in the upper reaches of Cauvery River Basin to ascertain the weathering status of the region. Also, because these sediments have been derived directly from igneous/metamorphic rocks without an intervening history of crustal and sedimentary recycling, their geochemistry provides very valuable information on weathering-tectonic-climate feedback processes as well as on the geochemical behavior of elements in first cycle sedimentary systems. This knowledge is very essential to the study of ancient sediments and soils as well as to understand the natural fertility of soils and sediments.

The Cauvery River Basin lies between latitude 10°7'N to 13°28'N and longitude 75°28'E and 79°52'E, covering an area of about 87,900 sq. km which is spread over the states of Karnataka, Kerala and Tamil Nadu. The river originates in
the Brahamagiri range of the Western Ghats at an elevation of 1345 m above mean sea level and travels nearly around 800 kilometers before joining the Bay of Bengal.

The Cauvery River Basin experiences a semi-arid tropical climate. The mean annual temperature of the Cauvery basin is 25 °C; however, in summer (March to May) the maximum temperature reaches up to 43 °C. The average annual rainfall of the basin is 1092 mm, which has an average elevation of about 630 m. The southwest monsoon is responsible for the rain in this area, which in just three months (June to August) accounts for 75% of the annual rainfall, 73% of the annual water discharge and 85% of the annual sediment transport. The region has only sparse vegetative cover, excepting in the peneplained areas, which are under cultivation.

The initial and final course of the river is easterly over the Mysore plateau (elevation 1000 m) and flood plains and delta region of Tamil Nadu respectively. Whereas, in between Mysore Plateau and Tamil Nadu plain there occurs a series of Block Mountains and the drainage pattern of the river becomes trellis resulting in an overall southerly flow for the main channel. Based on a variety of geomorphological evidences and seismicity of the region the catchment area was shown to have been subjected to periodic uplift since Middle Mesozoic along Archean and Proterozoic faults and shear zones. Relying on geomorphological characteristics, a chronology of events that determined the landscape of southern India, from Jurassic to Recent has been proposed. However, no information regarding the absolute timing of the tectonic activities in the region is available. Interestingly, whereas the peneplained regions of the uplifted plateau are made predominantly of Archean gneisses and schists in the catchment area, those constituting high mountains (up to 2700 m) are commonly
made of charnockites. This mode of occurrence of gneisses and charnockites had led early geologists to suggest a denudational origin for the charnockitic hills.

The main lithologies of the drainage basin include 3300-2900 Ma TTG type Peninsular gneiss their granulite equivalents, around 2500 Ma old, tonalite gneiss, charnockite and granites and very minor amount of supracrustal rocks. Whereas the upper reaches of the river drain dominantly through amphibolite facies gneisses, the lower reaches drain predominantly through granulitic rocks; the uplifted and rejuvenated segment also includes predominantly the charnockites and other granulitic rocks. The gneisses are strongly foliated, migmatised and extensively sheared and the dominant minerals are plagioclase, quartz, K-feldspar, biotite and hornblende. The accessory phases include magnetite, apatite, sphene and zircon. The foliated charnockites derived from the gneisses also have similar mineralogy excepting the replacement of hornblends by hypersthene and appearance of garnet. The upland massif charnockites of Anaimalai and Cardamom hills have quartz, K-feldspar, plagioclase orthopyroxenes, magnetite, ilmenite, hornblende, and biotite as dominant minerals with zircon and apatite as accessory phases.

Field evidences and mineralogical observations in the upper reaches of Cauvery catchment area reveal that the gneisses are more susceptible to weathering compared to massive granites or charnockites, which stand out relatively fresh in the profiles. Nilgiris, Billigirirangan, Shevroy and Sankaridurg hills are good examples of massive character of charnockites and granites. Gneisses, their compositional banding and structural complexities such as folds, faults, lineation and foliation planes have a great effect on the intensity of weathering because these structures control the water
flow and therefore the rate and sequence of weathering. It is also noticed that the intensity, orientation and depth of the weathering front depend on the spacing and orientation of foliation planes. It is very rare to see the weathering front moving vertically downwards. More commonly saprolitic materials underlie fresh and saprolith. A blanket of brownish red regolith overlies all these. Rarely the regolith shows any evidence of having been exclusively derived from the rocks below. In the gently sloping to flat foothills the regolith attains a maximum thickness of about one-meter. In the areas studied and visited we have not come across typical, horizonated, soil profiles in the 'classical' sense.

The rocks studied are basaltic to dioritic to granitic in composition. However, neither the chemical nor the mineralogical composition has any significant effect on the weathering intensity. The clay fraction in the regolith is uniformly low everywhere. In areas underlain by biotite-rich gneisses or their mafic equivalents, the clay fraction in the regolith has significant amount of chlorite, however, in other cases smectite is the dominant clay mineral followed by kaolinite and illite. Even the highly weathered materials adjacent to fractures, which have soil-like appearance, have very low content of clay (maximum 5%). This indicates a very high degree of physical weathering without any significant chemical change. The mineralogy of the suspended load sediments of the Cauvery river water is reported to include dominantly feldspar and montmorillonite (~70%) and decreasing amounts of quartz, kaolinite and illite. Similarly, the solute chemistry of the river water is shown to be in equilibrium with albite, montmorillonite, and chlorite and sometimes with kaolinite. Thus, the chemistry of weathered products of the sediment sources to the river is consistent with that reported for the suspended and solute load of the river. All these
chemical features suggest that the rocks of the region were subjected to only minor chemical weathering.

Although the rocks have been physically broken down along foliation planes, fractures and compositional discontinuities, secondary mineral (such as chlorite, smectite, kaolinite and Fe-oxyhydroxide) formation is insignificant. In case of gneisses, there is little chemical change even up to the stage of saprolite development. Only in the soil/regolith there is some loss of Ca, Na, Sr, Ba, Mg and SiO₂. Other elements such as Fe, Mn, Al, Cr, Ni and REE all show enrichment relative to TiO₂ in areas which have developed profiles by \textit{in situ} weathering. The chondrite normalized REE patterns show little change excepting a slight flattening of the patterns because of greater HREE mobility during weathering. Clay minerals also have flattened REE pattern because of relative HREE enrichment. The depletion and the enrichment of different elements appear to be related to mild leaching of primary mafic minerals by meteoric water rather than by mineral breakdown.

The behavior of elements in amphibolite weathering profile is very different, probably due to formation of Mg bearing secondary minerals in saprolite stage. Weathering of komatiitic amphibolite has resulted in the mobilization and redistribution of REE (as also other immobile elements) without significant fractionation excepting a loss of Eu. Within the profile there is an enrichment of REE in the very initial and in the advanced stages of weathering, effected by different mechanisms; the intermediate saprolite stage shows a complementary loss. Weathering and associated elemental mobility and redistribution seem to have been mediated by microbial activity.
Weathering profiles developed over granite bedrock, at Halagur and Hogenelal, exhibit a smaller degree of weathering in the field relative to the Peninsular Gneisses. In both the profiles immobile elements such as Ti, Al, Fe, Mn, Ni, Cr and REE show enrichment, whereas Si, Ca, Na, Ba and Sr are mobile and depletion is noticed. Anamolously high concentration of Ti, Fe, Mn and REE, more so of HREE is, however, not only a result of weathering but addition from extraneous sources (because granites at both the areas are associated with highly weatherable amphibolite or pyroxenite) as well. The chondrite normalized REE patterns show that not only the abundance level has increased, relative to the bedrock, but also the patterns become somewhat flat indicating that mobilization of REE more so of HREE had occurred within the profile. The positive Eu anomaly of the fresh rock is also diminished with increasing extent of weathering; however, the abundance is still more than that of bedrock.

The extent of chemical weathering and mobility of elements in two of the charnockite weathering profiles is more or less similar to the weathering of gneisses. Interestingly, it is noticed that physical differentiation and spatial distribution of sediments can occur within a few tens of meters of transport by flowing water; however, the process of overall homogenization of sediments also goes on simultaneously.

Chemical Index of Alteration (CIA) values of different samples in all the profiles studied in the region indicate that the chemical weathering is either of the incipient stage or at the most reached to a slightly higher extent. In almost all the profiles CIA values of fresh rock, saprolith and saprolite varies in a narrow range
between \(-50\) to \(-60\). Only the more weathered material immediately adjacent to fracture planes the CIA value has gone up to \(-74\). CIA values of this extent suggest that the rocks have suffered only incipient chemical weathering for the extent of physical weathering undergone by them.

Thus, we observe very limited extent of chemical weathering; however, there is significant grain size reduction and loss of cohesion. It is also observed that neither the topography nor the thickness and the chemistry of soil and nor the vegetative cover indicate any extensive duration of exposure. The thin soil cover is a regolith and seems to have formed predominantly by physical weathering of rocks a feature common to semi arid regions. The solute and suspended load chemistry of the river corroborates the suggestion of physical weathering and erosion dominated denudational regime to the river. This would imply that although the rocks are Archean in age, they must have been exposed geologically very recently. Thus, the geochemical characteristics of weathering and its products of the Cauvery catchment area corroborate the suggestion that this region has been undergoing periodic uplift thereby continually exposing fresh rocks for weathering.

A region subjected to uplift experiences a high rate of erosion because of several geological, climatic and biologic factors. During soil formation, if the soil formed earlier is retained \textit{in situ} then it will lead to more chemical weathering and soil formation mainly because of increased biological activities. However, if erosion removes the early formed materials, as soon as they are formed, then chemical weathering and soil formation are inhibited. This is a characteristic feature of areas, which have been recently uplifted or undergoing uplift. Rapid physical erosion
accompanying uplift, resulting in build up of thick sedimentary deposits in the flood plains and deltas, is also probably responsible for short exposure of rocks for weathering. Thus, the geochemistry of the weathered materials including regolith/soil and saprolite in the Cauvery catchment area and the thickness of the soil itself strongly point to a recent or ongoing uplift of the region. If the incipiently weathered materials on charnockitic and gneissic hills were rapidly removed without loss of cations, transported and deposited, then the formation of fertile farmland along the course of the Cauvery river and its delta would contain most of the biologically needed cations, making them very fertile.

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