Article

Unusual death of millipedes (Diplopoda) towards the north of the Varkala Cliff section near Papanasam, Kerala, India

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Abstract
The cliff section at Varkala, Kerala consisting of clay, lignite band, clay, sandy-clay, sandstone of Mio-Pliocene age. This sedimentary sequence is overlain by a thick laterite. Above the lower lignite band, in the exposed clay beds several struggling and dead millipedes can be observed. Their death is probably due to the action of dehydration related to the sulphuric water infiltration in the sediments. However, it still remains a mystery why these millipedes choose such a toxic environment to create their habitat?

Keywords unusual death; millipedes; India.

1 Introduction

Millipedes are segmented arthropods and are mostly found plentiful during the monsoon seasons. In general, they are found mostly confined to dark, dam, cool and moist environments. Most of them feed on decaying leaves, vegetation, fungi, organic matters in soil and sometimes their own fecal matter. More than 10,000 species of millipedes has been identified. They have a life span of one year to about ten years to reach its maturity. After mating, the female millipedes burrow below the soil to lay about 50 to 100 eggs. In certain circumstances, the millipedes responsible in destroying crops are treated as pests. Current knowledge on the effects of climate change, food quality and land cover on millipedes is reviewed, to explore the potential responses of the arthropods group to global change. Climate warming could result in higher rates of population growth and have positive effects on the abundance of some temperate species (David, 2009).

2 About the Area

The area is located on the sea coast of Papanasam, approximately 3.5 km from Varkala town (Fig. 1). The cliff section of nearly 27.69 m thick and consists of clay, lignite band, thick horizon of clay and sandstone. This thick sedimentary sequence is overlain by laterite (Fig. 2). According to Paulose and Narayanswamy (1968) the section at Varkala coast represents a Mio-Pliocene age. The palynalogical studies of the carbonaceous layer at the base suggest an Early Miocene age to the section (Ramanujan and Rao, 1977). The lithosection consisting of sandstones, variegated clays and lignite bands representing a littoral facies (Kumar et. al., 1990).

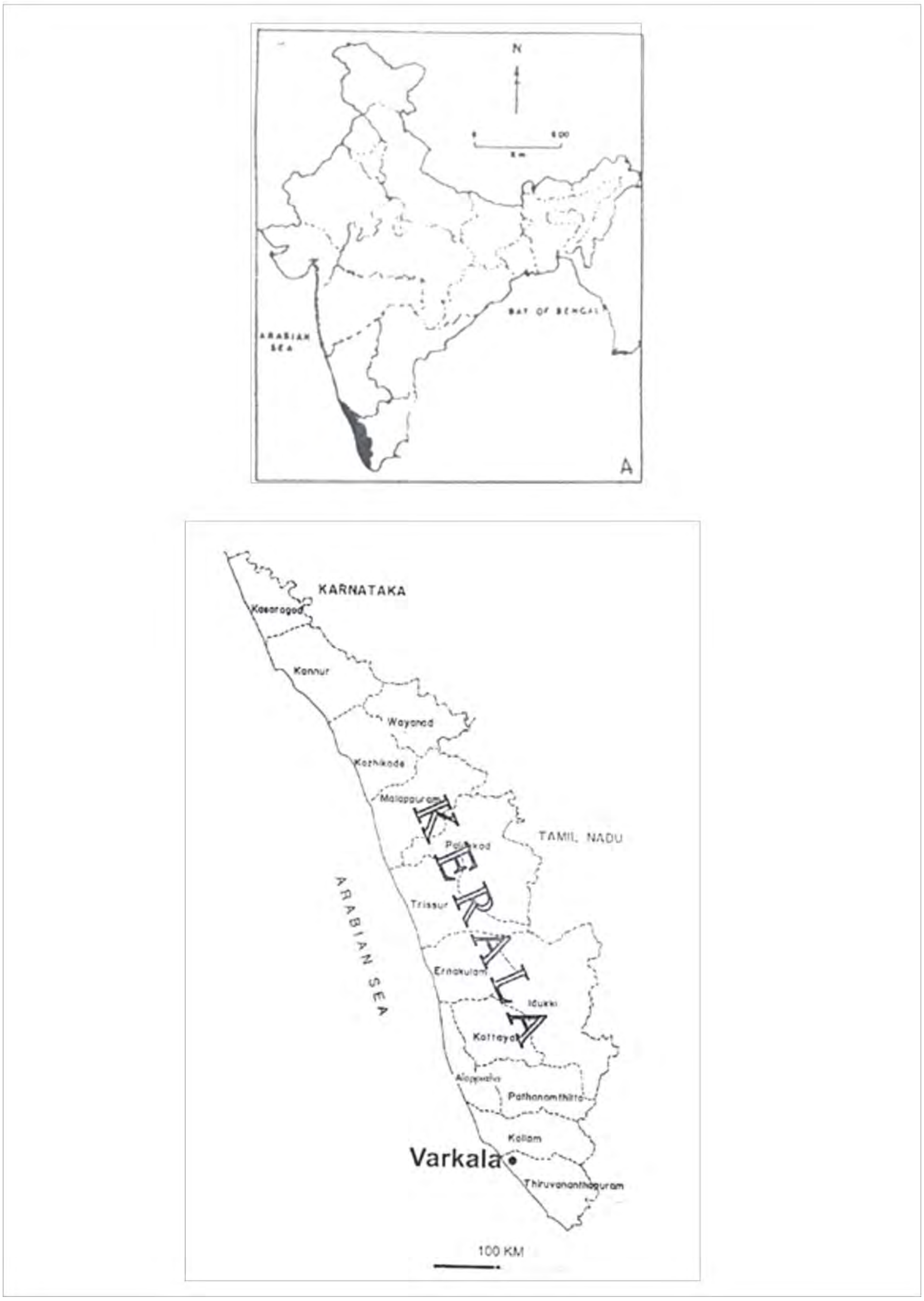

Fig. 1 a) Location of Kerala in India. b) Location of Varkala in Thiruvanthapuram.

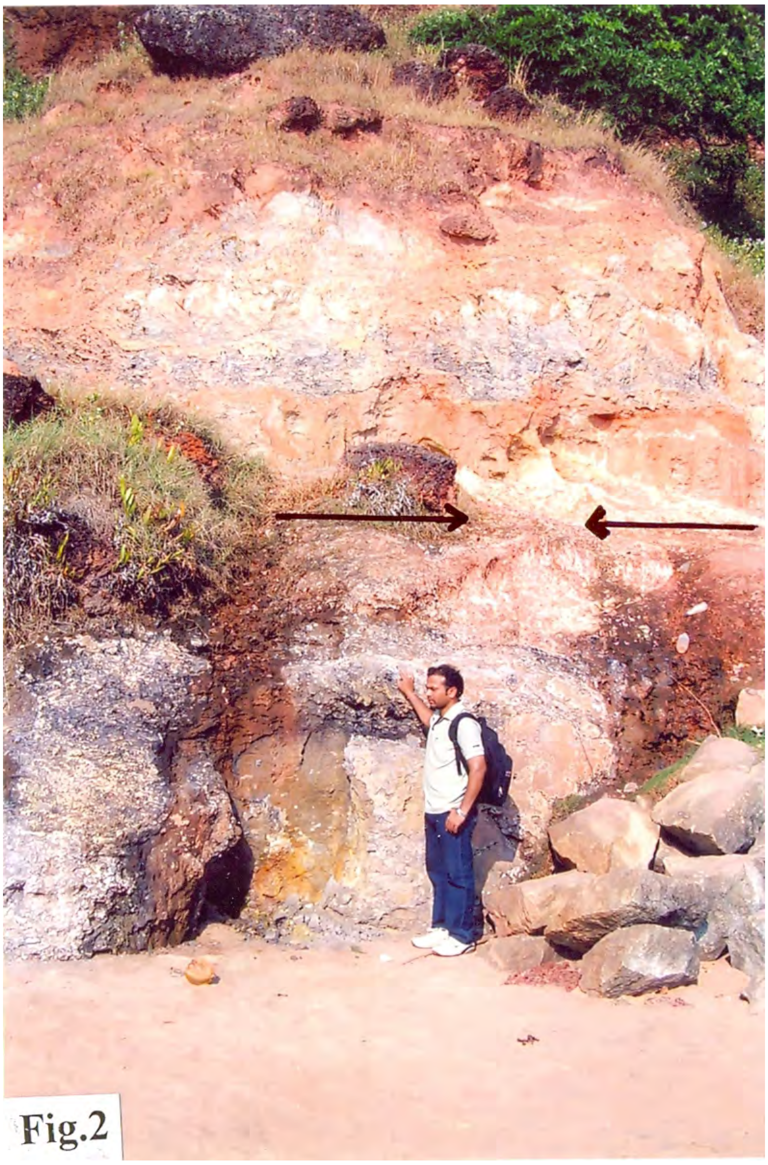

Fig. 2 The sequence consisting of sandstones, variegated clays and the lower lignite band towards north of Varkala cliff section. Note the arrow points at the site of the dead millipedes.

3 Observations

In the area under study, yellowish patches of sulphur is observed on the overlying and underlying sediments associated with the lignite deposit. The sediments and the percolating spring water have some sort of pungent odor of sulphur. Above the lignite band, within the exposed clay beds, several dead and half- curled struggling millipedes can be observed (Fig. 3). Most of the millipedes were found to have died out of their burrows, within their burrows, and during transit from crevasses to crevasses. Around the dead millipedes, numerous circular soil mounds of millipede burrows are also observed (Fig. 4). A few half-dead, curled and struggling millipedes (light pinkish-brown colored) were also observed. However, the dead millipedes were found to have lost their coloration and have attained a nearly albino character with all its delicate parts preserved intact. These dead millipedes have attained a slight brittle nature, when broken are hollow from inside.

The sandstone in thin section shows ill-sorted nature. In general, the detrital grains are dominantly angular to sub-angular, however at places rounded to sub-rounded grains are not uncommon. Quartz forms the dominant mode within the detrital components with minor amounts of feldspars and heavy minerals. In plane polarized light the detrital components are found to be cemented by a brownish, clay-rich matter within which dark brownish-black carbonized plant matter and brownish-red plant resins are observed (Fig. 5). Within the lignite bands and the overlying clay sediments yellowish patches of granular sulphur is observed. The percolating spring water also has a pungent smell of sulphur. The clay sediments around the dead millipedes were subjected to pH determination following the standard procedure adopted by the pedologists. The pH of the clay sediments ranges from 2.9 to about 3.5, indicating a highly acidic environment.

Fig. 3 Photograph exhibiting clusters of dead millipedes along with the struggling and half-dead (pink colored millipedes). The yellowish color of the sediments representing the sulphur- rich patches.

Fig. 4 Clusters of dead millipedes around the crevasses. Note the circular soil mounds of millipede egg-lying burrows towards the right hand corner of the photograph.

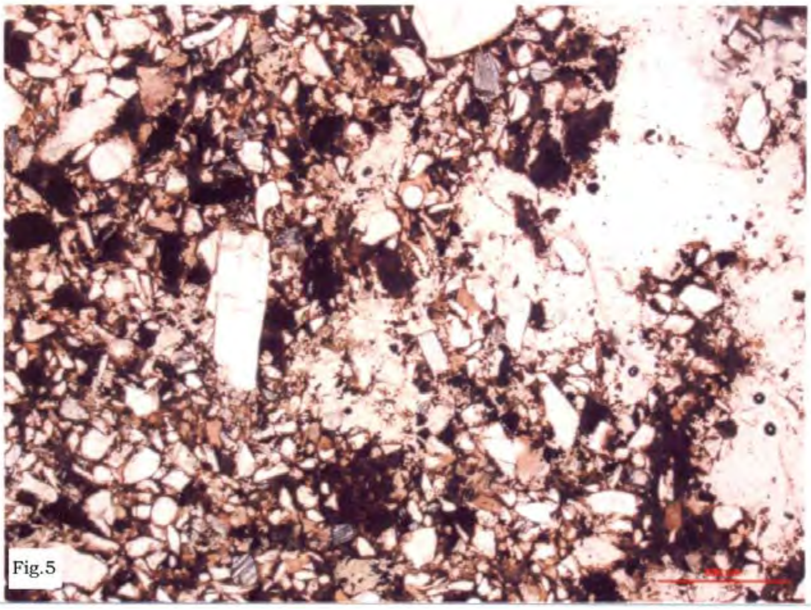

Fig. 5 Photomicrograph of the overlying sediments. Note the angular to subgrounded quartz grains set in a clay-rich matter within which black carbonized remains can be observed. Scale of the photo 100 μm.

In the present study, two possibilities probably exist for the death of the millipedes:

a) In most cases, the lignite deposits are associated with pyrite, occurring in a disseminated form, as well as found to replace parts of the woody matter. To ascertain the pyrite content, the sediments were disaggregated and observed under a binocular microscope. However, the sediments were found to be totally devoid of any pyrite.

According to Silverman (1967) two mechanisms of bacterial (*Thiobacillus ferrooxidans, Ferrobacillus ferrooxidans*) pyrite oxidation occurs concurrently i.e. the direct contact mechanism which require physical contact between bacteria and pyrite particles for biological pyrite oxidation, and the indirect contact mechanism according to which the bacteria oxidize ferrous ions to ferric state, thereby regenerating the ferric ions required for chemical oxidation of pyrite. The oxidation of pyrite by bacterial action results in the formation of sulphuric acid and ferric sulphate. It is quite probable that whatever minor amounts of pyrite were in existence must have been completely oxidized forming a toxic and acidic environment due to bacterial action and may be the cause for the death of the millipedes, as suggested by Silverman (1967).

b) The oxidation of sulphur or sulphides for energy production is restricted to the bacterial genus *Tiobacillus*, the genus *Thiomicrospira*, and the genus *Sulfolobus*. These bacteria all produce sulphuric acid, i.e. hydrogen H^+ and sulphate ions, SO_4^- as a metabolic product (Brieley, 1978). As stated above, the pH of the overlying and the underlying sediments range from 2.9 to 3.5 indicating a highly acidic environment. In the area under investigation, the yellowish patches of granular sulphur that is commonly observed on the lignite bands as well as on the overlying and the underlying sediments. The oxidation of sulphur by bacteria as suggested by Brieley, 1978, may be the prime cause for the generation of sulphuric acid and the associated toxic environment. As hydration reaction of sulphuric acid is highly exothermic, the millipedes must have taken advantage for quick hatching their eggs as indicated by the numerous egg lying burrow mounds found in the sediments overlying the lignite bands.

Sulphuric acid is an excellent dehydrating agent. Thus, the presence of sulphuric acid in the sediments at Varkala made the environment toxic and dehydrating for the survival of the millipedes. Most insects have a good sensitivity towards any toxic environment; however, it still remains a mystery why these millipedes were driven in such a toxic environment and finally die?

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