endary Holyrood Park (including the famous Hutton's locality on spectacular Salisbury Crags). Much to the chagrin of certain connoisseurs, the official programme for an exciting visit to the Scotch Whisky Heritage Centre for discovering the history and mystery of the Spirit of Scotland was scheduled for accompanying persons (only).

A number of invigorating field excursions were arranged (3–11 September) for the participants to view the renowned geology and scenery of the Scottish Highlands and Islands (Ballachulish, Great Glen: Kinlochbervie, Northwest Highlands; Sligachan, Isle of Skye) with Keith O'Nions, Mike O'Hara, Ben Harte, David Pattison and others as leaders. This is indeed an added academic attraction of the Conference and an unforgettable geological feast, in the true sense, to the participants

The two-page extended abstracts of all the papers (oral and poster presentations) were printed and brought out as a voluminous special number (vol. 58A) of the magnificent *Mineralogical Magazine* (published by the Mineralogical Society, London) in two parts: the first part containing Abstracts A–K (pp. 1–504) and the second part containing Abstracts L–Z (pp. 505–1009) The first part also contains a useful Author Index (pp. ii–viii) and an informative Subject Index (pp. ix–xxxii). Seven erudite participants (S. L. Goldstein, B. Harte, C. J. Hawkesworth, A. W. Hofmann, R. K. O'Nions, N. Shimizu & B. J. Wood) authored or co-authored 6 or more than 6 abstracts; they consumed, along with their co-authors, a total of 92 out of 1009 pages! This vol. 58A of the *Mineralogical Magazine* is destined to become an inexhaustible storehouse of geochemical information in the widest sense and also an exceedingly valuable reference work of long-lasting value.

The scientific excellence and organizational grandeur of the 1994 VM Goldschmidt Conference made it a truly memorable one.

C. Leelanandam, Department of Geology, Osmania University, Hyderabad.

SCIENTIFIC CORRESPONDENCE

Geochemical basis of tropical endomyocardial fibrosis

We have the following comments on the letter from P. V. Sukumaran[1]:

1. Our studies show an overlap in the incidence of endomyocardial fibrosis with the areas where deposits of monazite occur in Kerala. Cerium tops the list by percentage weight among rare-earth elements (REE) in monazite. Since the cardiac tissues of patients contain more cerium and, to a lesser extent, thorium than the control samples, it is logical to pursue the possible pathogenetic role of cerium in the disease. Cerium is the most soluble among REE and is concentrated by planktonic algae and probably tubers. How it gets into the cardiac tissues remains to be worked out. It is, however, likely that the deficiency of magnesium may enhance the absorption of cerium through the gut as it does for certain other toxic elements like Pb and Al.

2. The impression that REE are stable and the chances of their uptake by plants are remote is not necessarily correct. While the major portion of the monazite may be insoluble and hence not bioavailable, the work on coconut palms shows that they can accumulate cerium from the environment[2]. Similarly, a laboratory experiment using *Coleus parviflorus* has shown that plants can accumulate cerium from the experimental culture medium[3]. In fact, a geochemical hypothesis has been suggested for the causation of root (wilt) disease in coconut palms. The possible factors that may govern the uptake of REE from the environment are discussed elsewhere[4].

3. The map of Kerala was given merely to indicate the preferential deposition of monazite along the coastal strip, where most of the patients also come from. The deposits did not claim to indicate their minability or mechanism of deposition.

4. Elevated levels of REE and Th in faeces denote the consumption of these elements and their probable route of entry into body tissues.

5. Mere presence of certain elements in the soil does not suggest a causal role for them in disease. The claim that other elements such as Al present in Kerala soil should lead to increased incidence of Alzheimer's disease is, therefore, naive. In studying pathogenesis, the reason to look at certain elements is their high or low level in human tissues and not their concentration in the soil. Geochemical aspects are important to the extent they are necessary for investigating the pathogenetic mechanisms of RE and other elements.

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J. T. EAPEN
K. SHIVAKUMAR
R. R. NAIR
C. C. KARTHA
M. S VALIATHAN*

Sree Chitra Tirunal Institute for Medical Sciences & Technology Trivandrum 695 011, India
**Manipal Academy of Higher Education Manipal 576 119, India*

P. V. Sukumaran's reply:

Though I have clearly mentioned the shortcomings of the paper by Valiathan *et al* [1] from a geologist's point of view[2], I am elaborating below some of the points which may not occur to a medical scientist:

1. I do not contest the findings of the authors on the correlation of Ce with endomyocardial fibrosis (EMF). What I fail to understand is how the element Ce is presumably mobilized from a chemically inert and stable mineral like monazite. In fact, what promotes the selective concentration of monazite as beach deposits is its physical and chemical stability during rock decay.

2. There can be two pathways by which Ce reaches the human body. The mineral monazite goes into the biological system inadvertantly as a result of constant contact of the local population with the mineral sand of the area; the digestive and gastric fluids might then corrode the mineral releasing Ce for concentration in the cardiac tissues. An alternative possibility is that Ce reaches the system through the food chain wherein the element derived from numerous sources, including perhaps monazite, is bioamplified by plants, particularly the tubers. Analysis of Ce in tubers grown in monazite areas of the State can pinpoint the source. Study of faeces from the monazite belt of Kerala and Tamil Nadu for detrital monazite content, particularly for evidences of corrosion, can also give a clue to the source of Ce. The latter, however, needs extremely careful sampling.

3. I did not mention that REE are stable In fact, they are highly mobile under the low-pH tropical weathering environments. I only mentioned that monazite (the REE-bearing mineral) is much stable under weathering conditions.

4. The literature lists more than 200 minerals in which the REE content exceeds[3] 0.01% and about 70 other minerals are known wherein REE are major constituents, as in monazite. In addition, REE occur in the crystal structure of many major minerals like pyroxenes, amphiboles and feldspars. Alderton *et al.*[4] have shown that about 50% of REE in granitic rocks occur in major minerals and the remaining 50% in minor minerals. These minor minerals are by and large stable and do not undergo chemical weathering for the REE to be released. The major minerals mentioned above are abundant as constituents of rocks of Kerala and the whole of peninsular India. They are very susceptible to chemical attack in the low-pH weathering environments of the warm, humid tropics. The REE so mobilized into the ambient aqueous medium are available for biological uptake either through water or through the food chain. Accumulation of Ce in coconut plants must be through this pathway.

5. The monazite belt of Kerala is well-defined and not dispersed as one could make out from the map. The Neendakara–Kayamkulum belt is 22 km long and about 3 km wide from the seashore. The monazite content in this belt is 0.5–1.0% by weight. Another monazite belt is located in the Manavalakurichi region of Kanyakumari district in Tamil Nadu and is 6 km long from the Vallıyar river mouth to Colachal. This belt has a higher concentration of monazite (3–4%). A third monazite area in the country is the 18 km long Chattarpur coast in Orissa, though the monazite concentration here is much lower (0.29%)

6. The application of chemical fertilizers is indiscriminate among the innovative farming population of Kerala. The phosphatic fertilizers, chief among the chemical fertilizers, are manufactured from phosphorite rocks, which contain an average of 104 ppm of Ce (ref. 5). They also contain Cd (18 ppm) and many other toxic elements in bioavailable form. Study of the release of Cd into the groundwaters in the European agricultural lands has shown that continuous application of phosphatic fertilizers over a period of 30–40 years can elevate the groundwater Cd levels up to the permissible limit of 5 ppb. Cadmium is suspected to have an aetiological relation with Osteomalacia. A similar enrichment of Ce in groundwater derived from phosphatic fertilizers cannot be ruled out.

7. Obviously, there is need for interaction between the medical researchers and earth scientists. The following studies by appropriate agencies like the Centre for Earth Science Studies, Trivandrum, in collaboration with Sree Chitra Tirunal Institute of Medical Sciences, Trivandrum, would be fruitful.

(a) Measurement of Ce abundances in the groundwater of the monazite belt of Kerala and other regions mentioned above and adjoining low-monazite areas to ascertain whether excessive Ce is getting leached into the groundwater.

(b) Comparative field studies in the three areas mentioned above to confirm whether the incidence of EMF is higher in Manavalakurichi area compared to Neendakara–Kayamkulum area and whether similar incidence of EMF also occurs in the Chattarpur coast of Orissa. This needs field studies exclusively on the endemic population of the monazite belt.

(c) Field studies to confirm whether the Ce content in groundwater and in locally grown staple food is also higher in low-monazite areas, from where some of the EMF patients are sampled. If yes, this will confirm a different pathway for Ce to human beings.

(d) Analysis of causative Ce in the locally grown staple food of the inhabitants of the monazite belt *vis-à-vis* in the non-monazite-bearing adjoining areas

8. Finally, the presence of an element in soil, no doubt, does not suggest the incidence of a disease. But if its presence is in a bioavailable form, there is reason to look for a relationship. In its concentration as monazite, Ce appears to be non-bioavailable as is Al in bauxite. This is not to commit that Ce is not at all available. It may be available through numerous other sources, some of which may be anthropogenic and can accumulate in human beings through the food chain. Certainly, it is a subject of much interest not only for the medical researchers but for geologists as well.

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P. V. SUKUMARAN

Marine Wing
Geological Survey of India
Mangalore 575 003, India