CHAPTER 12

BASELINE GEOCHEMICAL DATA FOR MEDICAL GEOLOGY IN TROPICAL ENVIRONMENTS

Baseline geochemical data and geochemical maps are now proving to be extremely useful tools in epidemiology and medical geology. Information on the geochemical pathways and regional distribution of essential and toxic elements in the environment is now more easily available and there is greater understanding of the impact of trace elements in health and disease, their bioavailability and homeostasis. With the help of statistically significant data, it is now possible to pin point areas vulnerable to diseases that are clearly geographically and geologically linked.

Geochemical maps showing detailed distribution of various chemical elements in soils, stream sediments and water are now available in most developed countries. In developing countries however, due to a variety of factors such as lack of high precision instrumentation, funding, trained personnel, rugged and inaccessible terrains, among others, such maps are still not available. China, however, has shown remarkable progress in geochemical mapping since 1979, and there has been more progress in China than anywhere else in the world. It seems highly probable that from 1980 onwards, a larger area has been sampled in China than in all other countries combined (Darnley, 1995; Xie and Cheng, 2001).

Even though these geochemical maps were primarily used for mineral exploration, they are now used extensively as in the case of China, Finland, Sweden and Norway, for geomedical purposes (Tanskanen et al., 1988; Selinus, 1988). The delineation of the high-risk areas based on the levels of abundance of essential and toxic elements is done with this baseline data and when combined with geological information such as lithology, mineralogy and geomorphology, ***'geochemical maps'*** could be prepared. Many studies on medical geochemistry are carried out using these geochemical maps (Dissanayake and Chandrajith, 1999).

In view of the fact that clear associations and correlations between the geological environment and human and animal health is far more visible in

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developing countries of the tropical and sub-tropical areas of the world, Plant et al. (1996) emphasized the need for high resolution geochemical data in such countries. Dissanayake and Weerasooriya (1986) produced one of the first hydrogeochemical atlases of Asia and they demarcated areas where the groundwater fluoride concentrations are exceedingly high. This map proved to be particularly useful in site investigations for the deep well programme in the dry zone of Sri Lanka where endemic fluorosis incidences are alarmingly high. Similar maps in other countries, most notably in China, have also had a variety of uses particularly when geochemical diseases are prevalent (e.g. maps of Se, F in China, Figures 12.1 and 12.2, respectively). Some developing countries have recognized the great value of geochemical maps and as stated by Reedman et al. (1996), there should be greater priority given to such projects within their national programmes.

GEOCHEMICAL MAPPING - CHINA'S EXAMPLE

China has over the last 25 years, made truly remarkable progress and achievements in the field of geochemical mapping and mineral exploration. It has obtained regional geochemical data for 39 elements from several millions of stream sediment samples covering an area of more than 6 million km^2 (Xie et al., 1997, 2004). Such a vast programme has obviously generated massive quantities of useful geochemical data which could be used not only for mineral exploration, but for medical geology as well. China is therefore one of the countries presently leading in research on medical geology. Production of maps in China showing endemic fluorosis, endemic goitre, selenium responsive Keshan and Kaschin-Beck diseases etc have been greatly benefited by geochemical mapping programs. Figures 12.1 and 12.2 show the geochemical maps of fluoride and selenium distribution, respectively in flood plain sediments of Chain.

Recently Xie et al. (2004) developed the concept of **"*geochemical blocks*"** which has revolutionized geochemical mapping and mineral exploration in China. More than 80% of new mineral discoveries in China during the last 2 decades were due to information provided by China's National Geochemical Mapping (Regional Geochemistry-National Reconnaissance, RGNR) project which was initiated in 1979 (Xie et al., 1981; Xie and Zheng, 1983). The study of "*hierarchy of nested geochemical patterns*" for tungsten across the whole of China (Xie and Yin, 1993) demonstrated that there are very broad geochemical patterns above local geochemical dispersion halos, trains, and fans surrounding ore deposits, which had been the main topic of exploration geochemistry (Hawkes and Webb, 1962).

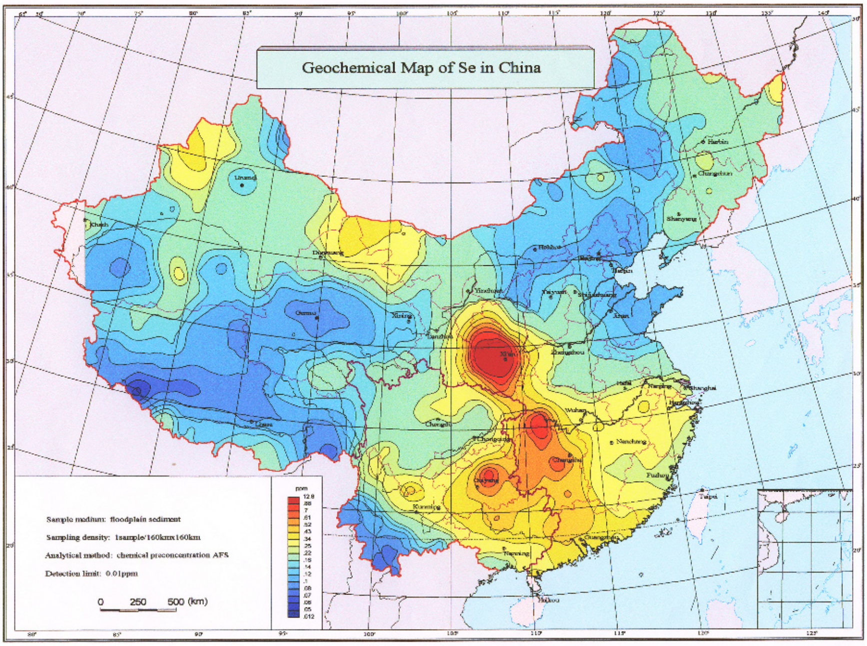

Fig. 12.1. Geochemical map of Se in China constructed using flood plain sediments (Courtesy of Prof. Xie Xuejing)

Table 12.1 shows the hierarchy of nested geochemical patterns and geochemical blocks. The concept of “geochemical block” with further modification has the potential of major application in delineating global “risk-areas” as affected by deficiency or toxicity of certain elements. Vast global areas such as those covered by the “goitre belt” spanning across Pakistan, Himalaya region, Bengal and Bangladesh, Vietnam and Indonesia could for example, be scientifically studied for their trace element behaviour using such geochemical concepts.

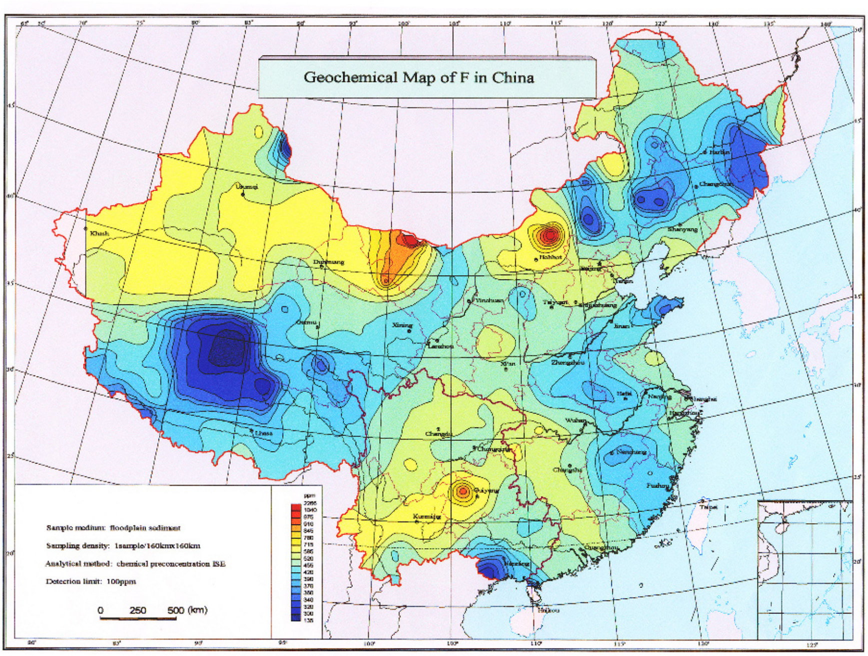

Fig. 12.2. Geochemical map of fluoride in China constructed using flood plain sediments (Courtesy of Prof. Xie Xuejing)

Table 12.1. Hierarchy of nested geochemical patterns and geochemical block ([a] The existence of geochemical continents can only be verified after wide-spaced geochemical mapping covered most part of the earth's land surface) (Xie et al., 2004)

Area (km^2)	Geochemical Patterns	
<100	Local anomaly	
100-1000	Regional anomaly (Geochemical region)	
1000-10,000	Geochemical province	
10,000-100,000	Geochemical mega-province	Surface expression of Geochemical block (given a 1000 m thickness)
100,000-1,000,000	Geochemical domain	
>1,000,000	Geochemical continent [a]	

SOIL MICRONUTRIENT MAPS IN TROPICAL COUNTRIES AND MEDICAL GEOLOGY

The importance of rock-soil-water-plant-human health relationships forms one of the basic factors influencing medical geology. As discussed in the earlier chapters, the chemical speciation of micronutrients and their bioavailability play a very significant role in the aetiology of geographically distributed diseases. A thorough knowledge of soil micronutrients of disease prone areas is therefore a necessary prerequisite for good epidemiological studies of regional medical studies. Micronutrient-poor soils are widespread throughout the world, most notably in the tropics and most food crops which form the staple diet of millions of people in the tropics are highly sensitive to the bioavailability of the micronutrients. Regional mapping of soil micronutrients, particularly in epidemiologically relevant disease-prone areas, is proving to be a most valuable exercise (White and Zasoski, 1999). Even though direct correlations between soil micronutrients and human health are rare, in tropical countries where most people live on home-grown food, such maps will have a variety of uses in agriculture, livestock, and human health.

Zinc is very well known as an important micronutrients and published maps of micronutrient-deficient areas in China indicated that about one-third of China's vast area was zinc-deficient (Zheng, 1991). These maps also showed areas of similar extent but different distributions that were low in B, Mo, and Mg while low copper areas represented only about 10% of the country (White and Zasoski, 1999).

The parent geological materials, paedogenic factors, geochemical environment, morphology and climate play different roles in the distribution of the micronutrients and there is, therefore a noticeable variation within and between regions.

Several methods have been used to produce maps depicting soil micronutrient content, plant-available micronutrients and areas of deficiency or toxicity at various cartographic scales. As reviewed by White and Zasoski (1999), small scale maps of global, continental or national extent are beneficial for a generalized overview of micronutrient deficiencies affecting livestock and human health. The micronutrient map of tropical Latin America was produced by Leon et al. (1985), and Kang and Osiname (1985) produced a similar map for tropical Africa. Among the problems observed in tropical Africa were (a) low total and extractable B, Cu, Mo and Zn in soils (b) local Mg deficiencies (c) iron toxicity in flooded rice soils. The parent geological materials were of more significance in the deficiency of the above elements in the soils.

Geochemical surveys of rocks, soils, vegetation, stream and lake sediments, surface and groundwaters, though used for purposes of mineral exploration have, however, yielded valuable information on micronutrients as well (Shacklette and Boerngen, 1984). Geochemical patterns of micronutrients in soils have been the subject of general studies (Thornton, 1987; 1993; Licht and Tarvainen, 1996; Plant et al., 2000). Recent advances in geographic information systems (GIS) and computer technology have facilitated the production of very informative geochemical maps depicting the status of micronutrients in the physical environment. Even though it is difficult to prove causality as against correlation, many attempts have been made to identify relationships between the geochemical environment and the incidence of diseases such as cancer, cardiovascular diseases, urinary stone formation. In certain lands such as Maputaland, South Africa, a tropical landmass covering an area of 50 x 100 km, the deficiency of micronutrients is extreme (Ceruti et al., 2003), and many diseases such as endemic osteoarthritis and dwarfism are prevalent. Geochemical maps of soil micronutrients will undoubtedly be of great value in such nutrient- impoverished lands.

FUTURE PROSPECTS FOR MEDICAL GEOLOGY

Medical geology is an emerging science and it is almost certain to achieve the status of an established field of science within a decade. Modern epidemiology requires a thorough understanding of the geochemical processes and pathways of essential and toxic elements and a clear integration of these different disciplines is being established.

Geochemical data bases such as those established, e.g., by the Global Geochemical Baseline Program of the IUGS/IAGC, British Geological Survey, Global Reference Network (GRN), Chinas' RGNR program. all provide valuable data useful in medical geochemistry. With recent advances in mapping, statistical techniques, extremely fast and accurate analytical techniques, the analysis of hundreds of samples rapidly, GIS based map making the possibilities for a better understanding of the aetiology of geochemically linked diseases, notably in the tropics is showing great promise.

Xie and Cheng (2001) have, for example, suggested that strategic deep penetrating NAMEG (NAnoscale Metals in Earth Gas) and MOMEO (MObile forms of MEtals in Overburden) geochemical methods developed in China are the optimum methods in geochemical mapping of deeply weathered lateritic terrains, so typical of tropical lands (Butt et al., 2000). The NAMEG method measures the nanoscale metal content carried out by micro-bubbles of "earth gas" generated form the interior of the earth. The MOMEO method measures the nanoscale content of mobile metals retained in soil when the carrier "earth gas" escapes into the atmosphere. Hidden ore deposits have been located using these techniques and medical geochemistry can be effectively integrated in such geochemical exploration programs.

Unlike in the past where only geological materials were analyzed and studied, it is now well established that for "terrain medical geochemistry" to be of use to the public and the health authorities, all samples from the area, i.e. rocks, minerals, soils, water, plants and food need to be studied together and correlated with in vivo studies. Such an approach has been taken by the British Geological Survey in studies on medical geochemistry.

In the medical field too, advances being made in the physiology of the human body, biochemical mechanisms of trace element ingestion, absorption and rejection, cell biology and inter-cellular chemical mechanisms may point to a greater need for the understanding of trace element geochemistry. The role of inorganic minerals such as apatite in the human bones and teeth is, for example, an area of research of extreme interest and which calls for a co-ordinated effort by geochemists, mineralogists and experts in human physiology. Among the other areas of interest are the iodine deficiency disorders (IDD), trace element-enzyme related diseases, natural radiation and mineral particles in the air.

"The human body is only a small part of a larger geochemical cycle. Medicine stands to gain by the proper understanding and application of Geology"