Developments in Environmental Science, Volume 5
D. Sarkar, R. Datta and R. Hannigan (Editors)

ISSN: 1474-8177/DOI:10.1016/S1474-8177(07)05001-2

Chapter 1

What goes around comes around: Today's environmental geochemistry

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Abstract

What is environmental geochemistry? Is it simply the application of geochemical techniques to environmental media such as water or soil? Is it the study of contaminants and pollutants? Is it all low temperature geochemistry exclusive of the biosphere and natural weathering processes? For certain the definition is complex. The field is clearly diverse as is evidenced in this book. Indeed this book best represents the complexity of the field, a snapshot, if you will, of concepts and applications in the field. Bearing in mind that the field is ever changing, a dynamic and evolving discipline, we provide a brief historical perspective and an attempt to define today's environmental geochemistry.

1.1. Introduction

Many of us call ourselves environmental geochemists. If asked what that really means, it is difficult to explain. The boundaries between the scientific disciplines are significantly blurred. But were they always so blurry? Is there a place and time one can point to and say that "this" is the beginning of the field? First one has to define what environmental geochemistry is. Geochemistry is, most broadly, the study of the chemical composition of the earth and other planets, chemical processes, cycles, reactions that govern the composition of rocks and soils, and temporal and spatial changes in these controlling factors. While interactions with the other earth systems is implied they are not explicit. Biogeochemistry, the field of study centered on chemical, physical, geological, and biological processes, cycles, and reactions that govern the composition of the natural environment (including the biosphere, the hydrosphere, the pedosphere, the atmosphere, and the lithosphere), is more closely aligned with the concept of environmental geochemistry. However

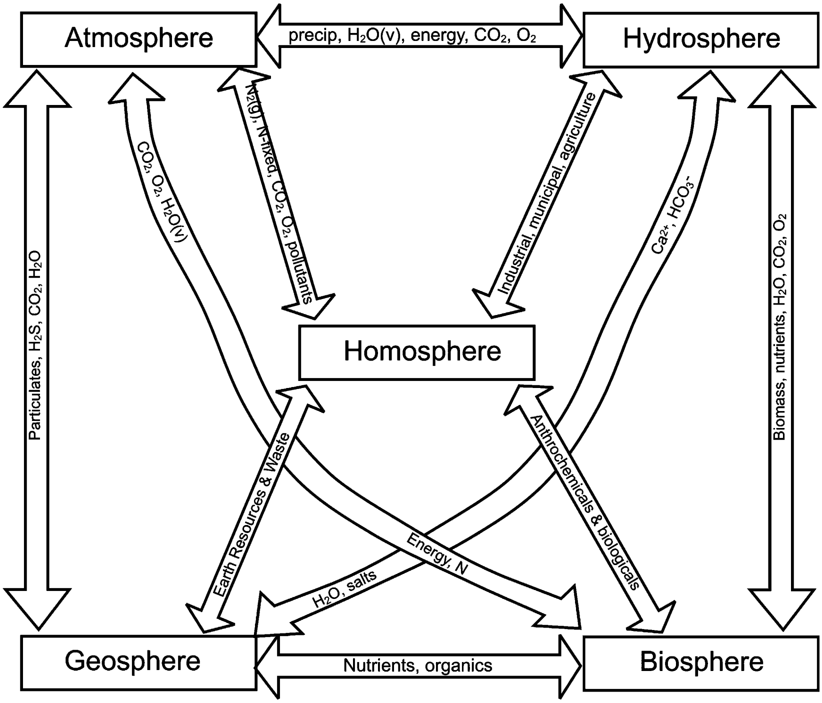

Figure 1.1. Illustration of the earth systems showing the linkages between the systems and the interactions of the homosphere with each.

today's environmental geochemistry is truly a hybrid between biogeochemistry and geochemistry. Environmental geochemistry is the field of study integrating the study of earth's chemical composition and earth system interactions with the interaction of humans with these systems. Therefore, a new "sphere" or dimension exists in environmental geochemistry that is mindful of the human interactions with the earth systems whether natural or man-made (Fig. 1.1).

1.1.1. What goes around …

With environmental geochemistry defined as above it is possible to explore the history of this field and set this book in the context of where the field has been and where it is headed. Scientists have long explored the relations between mankind and the earth. As early as 1766 with Henry Cavendish's exploration of arsenic in soil, natural scientists understood that chemicals in the soil could have profound impacts on human life. Cavendish, in his fundamental study on the effect of lightening on soil (Cavendish, 1767), was able to duplicate the processes that produce nitrogen gas. Not long after Cavendish found that nitrogen gas could be generated from soil, Nicolas de Saussure showed that plants require nitrogen from the soil (Saussure, 1804). Connecting the observations of Cavendish and de Saussure, Thaer developed the humus theory for soil suggesting that "organic substances" are the primary sources of energy in soils (Thaer, 1846). It was Davy (1813) who extracted "gooey" substances from soils and in so doing unknowingly uncovered the role of carbon dioxide–carbonic acid in soil formation. One might consider Davy's work as the "moment" when the science of geochemistry and the environment were connected. But no one connected the two in the literature until Dumas stated "Everything that the plants take from the air they give to animals, the animals return it to the air; this is the eternal circle in which life revolves but where matter only changes place" (Dumas, 1841). Dumas followed this insightful comment with a seminal collaborative essay with Boussingault (Dumas and Boussingault, 1842) where they discussed how the "mysterious cycle of organic life on the globe" worked by plants drawing matter from the atmosphere to create organic substances (Davy's gooey substances), and how these substances are eaten by animals, who return these "materials to nature's grand reserve upon their death and ultimate decay". Here is the start of the field of biogeochemistry and the development of this fields focus on carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulphur (CHNOPS) cycles. Where did the arsenic work of Cavendish go? How were humans, so fundamental to the studies of Thaer, the father of agronomy, so soon removed from the cycles of matter on the planet? Alas hindsight is 20/20. What goes around, thankfully, comes around.

Why focus on the history of soil chemistry and agronomy in an attempt to outline the history of environmental geochemistry? As the fields of geochemistry evolved and fundamental advances in our understanding of natural chemical processes on the planet were made, it is in soil science that the cycles and connections between the earth systems are elucidated with humans as actors in these cycles. For example, during the early and mid-1800s humans still had relatively little impact on the global cycling of nitrogen except in agricultural regions. In fact, Liebig (1840), or more correctly Sprengel (1837), attempted to capture the interaction of crops (anthropogenic) and nutrients (natural geochemical processes). This smacks of biogeochemistry except that humans plant the crops so it is still more closely aligned with our earlier definition of environmental geochemistry.

Geologist Eduard Suess (1875) tossed out the term "biosphere", but being a geologist, approached the earth systems from a traditional geochemical perspective. The current meaning of biosphere within an ecological context can be traced to Vladimir Vernadsky (1926) some 50 years later. Of course this seems to foreshadow Lovelock's (1979) Gaia Hypothesis, but I digress. Vernadksy's fundamentally important contribution to the understanding of the interaction of the living and non-living earth systems cannot be underestimated. Vernadsky's view of the biosphere was a new way of looking at our planet. His work led to major advances in ecology and ultimately blurred the lines between geochemistry and ecology to establish biogeochemistry as the field of science exploring chemical processes and interactions between geosphere–atmosphere–hydrosphere and living organisms. Humans, though certainly living organisms, were thought to have little influence on the earth as a whole and were basically end-users of the earth's abundant matter and energy.

In the years between Vernadsky's work and advancing the newly emerging field of biogeochemistry around from to World War II something changed: not an "earthquake" but field of a subtle shift occurred on the continents. Ecologists working in terrestrial aquatic systems began to make connections between natural geochemical processes, the influence of these processes on lake chemistry and availability of nutrients, and human interactions with the landscape.

Odum (1959, 1963) noted that the cycles of N, O, and water had a gaseous component, and that these cycles had self-regulating feedback mechanisms making them "perfect". However, scientists understood the imperfection of their "model" cycles when humans were considered in the biosphere as early as 1965 when concern abounded over disruption of the carbon cycle by burning of fossil fuels (Revelle et al., 1965) and nitrogen cycle through the introduction of pesticides (Cole, 1966). So here we have it, the beginnings of environmental geochemistry as a discipline and the introduction of humans as major players in the structure and the function of earth systems. A snapshot of the state of knowledge in 1960s can be found in Bormann and Likens (1967).

1.1.2. … comes around

As this introduction to concepts and applications in environmental geochemistry is not intended as a complete compilation of all research in the field, let us fast forward to Radojevic and Bashkin (1999) who summarized the analytical approaches to environmental chemistry. What is environmental chemistry? It is just environmental geochemistry, which, by any other name, would smell as sweet but makes chemists feel more at ease. Radojevic and Bashkin summarize the human influence on the cycles of C, S, N, and P as well as the consequences of human influence (Table 1.1).

Table 1.1. Relative contribution of human and natural sources of SO_2, NO_x, CO_2, and hydrocarbons to the atmosphere

Component	% of total emissions to the atmosphere	
	Natural	Human
SO_2	50	50
NO_x	50	50
CO_2	95	5
Hydrocarbons	84	16

Source: After Radojevic and Bashkin (1999).

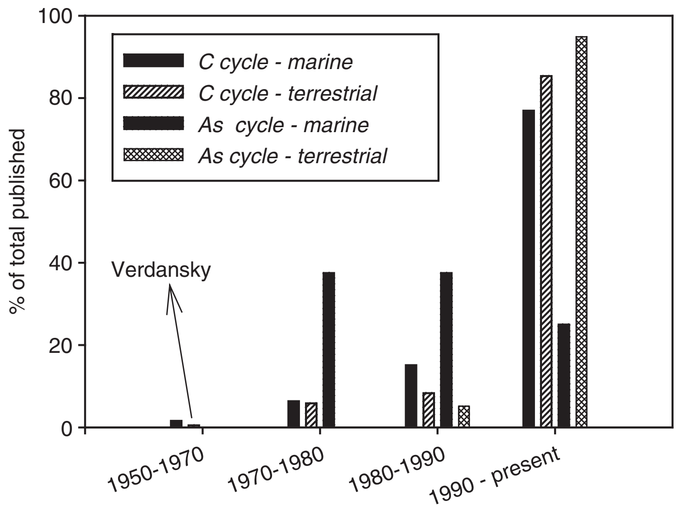

Figure 1.2. Relative percentage of publications derived from a GeoRef search using carbon cycle and arsenic cycle as keywords.

In 1999, humans contributed 16% of the hydrocarbon emissions to the atmosphere (5% of the CO_2), but up to 50% of the SO_2 and NO_x emissions. Human impact on the earth systems is no longer a subject of debate. Neither is the impact of these systems on humans. Witness the continued focus on arsenic in drinking water and the development of an intricate and relatively complete arsenic cycle based on a material's flow perspective (Ayres and Ayres, 1999).

So here we are in 2007. We are really not much farther along than Cavendish was in 1767 when he began his studies on arsenic. Much has changed over the intervening years between us and Cavendish. Publications in the field of environmental geochemistry are ever increasing (Fig. 1.2).

Although initially studies of the cycles of C and As were dominated by biogeochemists in the marine realm, terrestrial research has begun to dominate environmental geochemistry. As more and more research focuses on the relation of the homosphere to the other earth systems, disciplinary boundaries are obscured and the lines between once discrete disciplines such as geochemistry and biogeochemistry are now arbitrary, a vestige of the ''old days''.

Within this book you will find a great variety of environmental geochemistry topics ranging from mathematical approaches to exploring natural processes and their impact on the environment. Here we present a snapshot of environmental geochemistry as we know it today, much like it was in the beginning but with a larger vocabulary and few, if any, disciplinary boundaries. What goes around, comes around and we, as humans, are still in the thick of it.

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