Are all creatures created equal? (Geochemistry of Biosphere)

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By compiling many elemental composition data for marine and terrestrial plants and animals, Bowen (1966, 1979) noticed a remarkable similarity among them. Based on the so-called biological standard reference materials (SRM), Li (2000) confirms this observation (Figure 1). The plot of elemental compositions of the average soil against that of spinach (as representa-

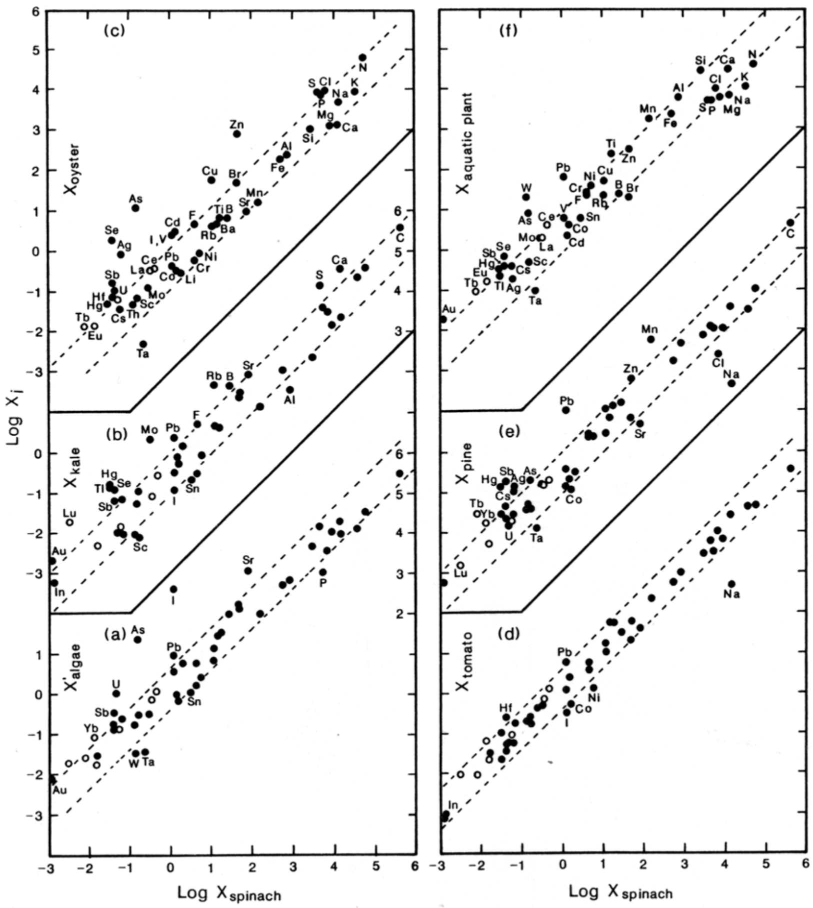

Figure 1 Plots of the compositions of spinach versus those of (a) algae, (b) kale, (c) oyster, (d) tomato leave, (e) pine needle, and (f) aquatic plant. Data by Gladney (1989), and Bowen (1979).

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第190回京都化学者クラブ例会（平成18年４月１日）講演

tive of land plants; Figure 2) or the average shale against that of algae (Figure 3) nicely separates elements into biophobe (solid circles and triangles) and biophile (open circles) groups. The biophobe elements have the enrichment factor E^{i}_{Al} of about one, and are mainly A-type ions (with electron configuration of noble gases) and lanthanides. These elements are also the very same elements that represent the factor 1 (F1) in the factor loading plots of Yamamoto's (1983) algae data in factor analysis (Figure 4). Most of these elements are probably incorporated into or onto biological cell as colloidal or very fine inorganic coating. The biophile elements have the enrichment factor E^{i}_{Al} of greater than 10, and are mainly A-type ions with long mean oceanic residence times (i.e. major ions in seawater), B-type ions (with outer electron configurations of d^{10}), and some transition-metal cations.

Partitioning of elements between solid particles and solution can to be adequately explained by the surface complexation model (Stumm *et al.,* 1970; Schindler, 1975; James and Healy, 1972). The major difference between inorganic and organic particles is that inorganic particles mainly have hydroxyle group (–OH) on surface due to hydration process, and organic particles can have hydrophilic functional groups (such as –COOH, $-NH_2$, –SH, in addition to –OH) on surface. These hydrophilic functional groups can form strong binding with B-type and transition-metal cations. This may partially explain the separation of elements into biophobe and biophile groups.

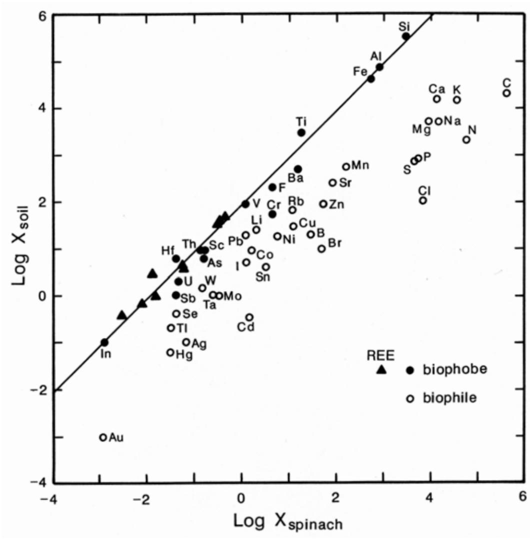

Figure 2 Plot of the compositional data for spinach reference material (SRM 1570) versus average soils (Li, 2000).

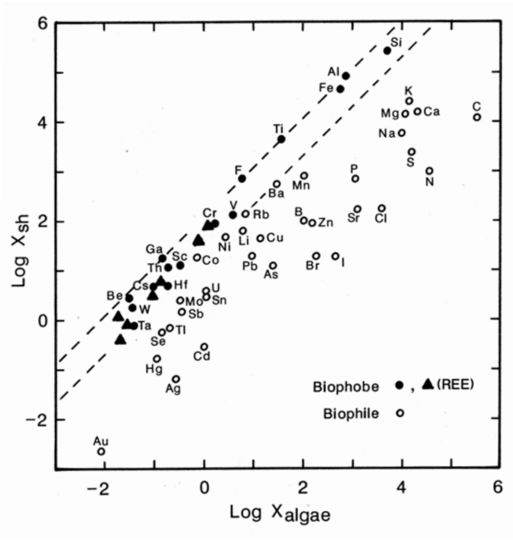

Figure 3 Plot of the compositional data for average algae versus average shale (Li, 2000).

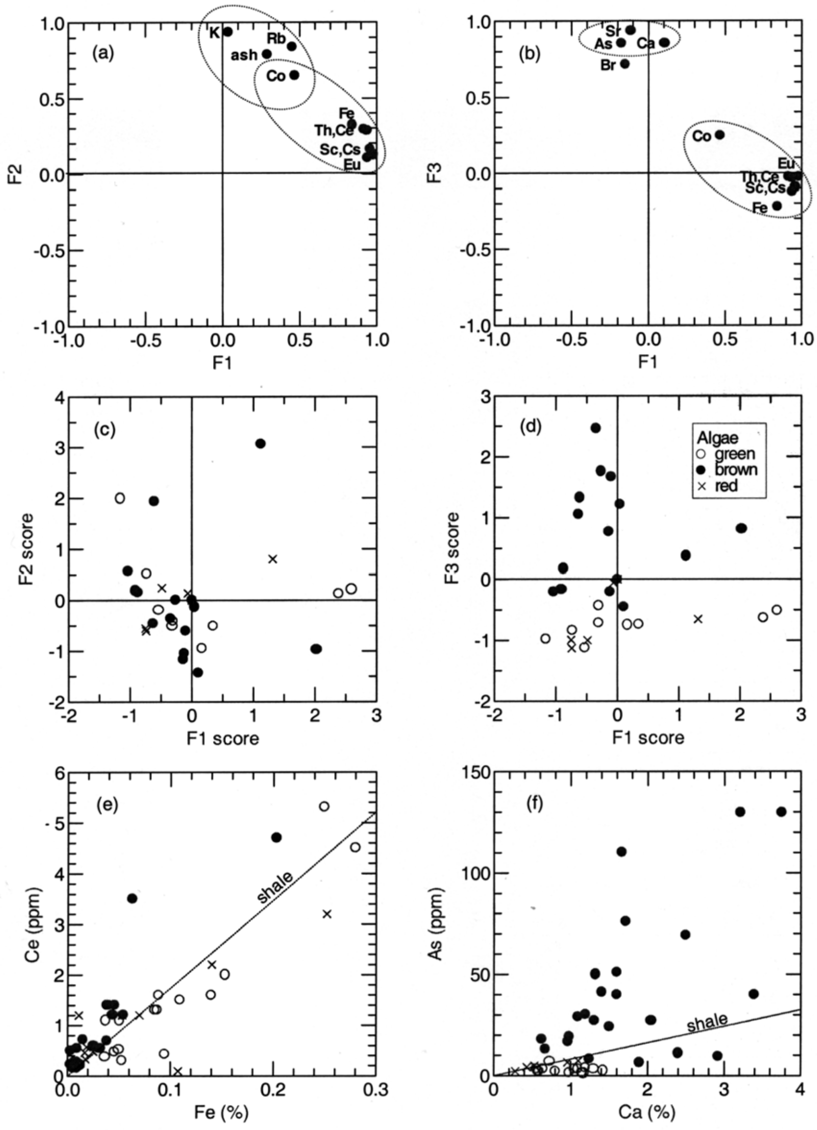

Figure 4 Factor loading and scores obtained from the factor analysis of Yamamoto's (1983) algae data.

The correlation plots of various human organs against human muscle compositions (Figure 5; data from Snyder *et al.,* 1975; Hamilton, 1979) again show their general similarity. It is not surprising to find that the average compositions of human body, diet and spinach are also very similar (Li, 2000). Human breast milk from several countries was studied by the World Health Organization and the International Atomic Energy Agency (WHO/IAEA, 1989). A few trace elements do show some regional variation, but the overall compositions are

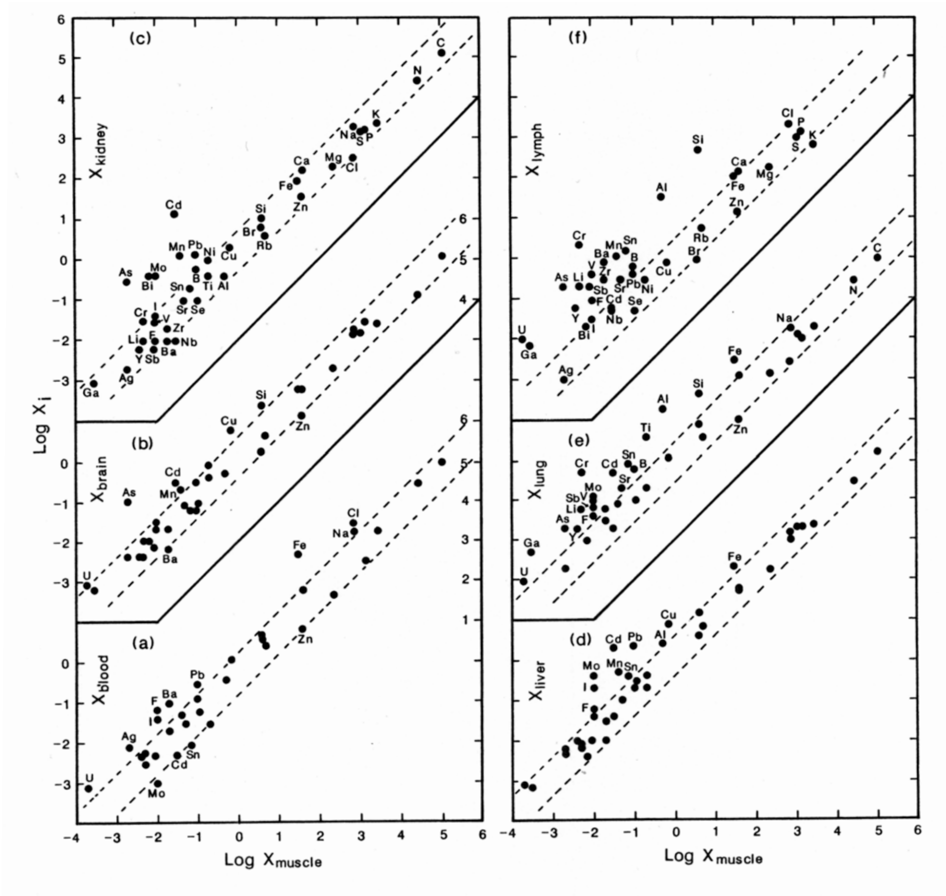

Figure 5 Plots of the compositions of human muscle versus those of (a) blood, (b) brain, (c) kidney, (d) liver, (e) lung, and (f) lymph.

similar to human muscle, except that Ca, F, and I are much higher in milk.

Results from factor analysis of the organic-rich Black Sea core data (H. Brumsack, personal communication) are shown in Figure 6. Factor 1 (F1) represents the elements associated with aluminosilicate phases; negative F1 carbonate; and F2 biophile elements associated with organic matter. Surface sediments (0–66 cm) are organic rich, and the samples below are mainly a mixture of shale and carbonates.

Accumulation of terrestrial plant material in swamps and subsequent burial and alteration through pressure and heat over geological time has resulted in coal deposits. Petroleum is thought to originate mainly from lipidic fractions of organisms and to have undergone various maturation and migration processes through geological time. As shown in Figure 7, the elements falling on or near the straight line have E^{i}_{Al} values of near 1 for Illinois coal relative to shale; thus, these elements in Illinois coals are mainly contributed by shale components. Most

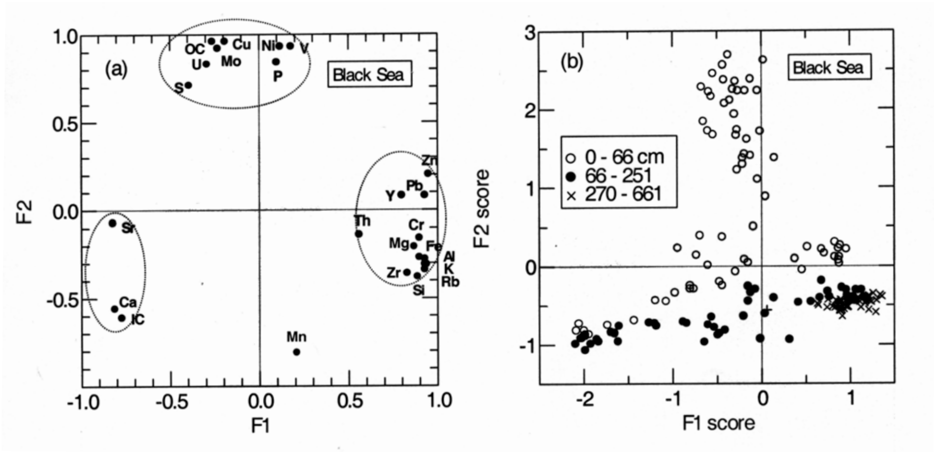

Figure 6 Factor loading and scores obtained from the factor analysis of Black Sea core data.

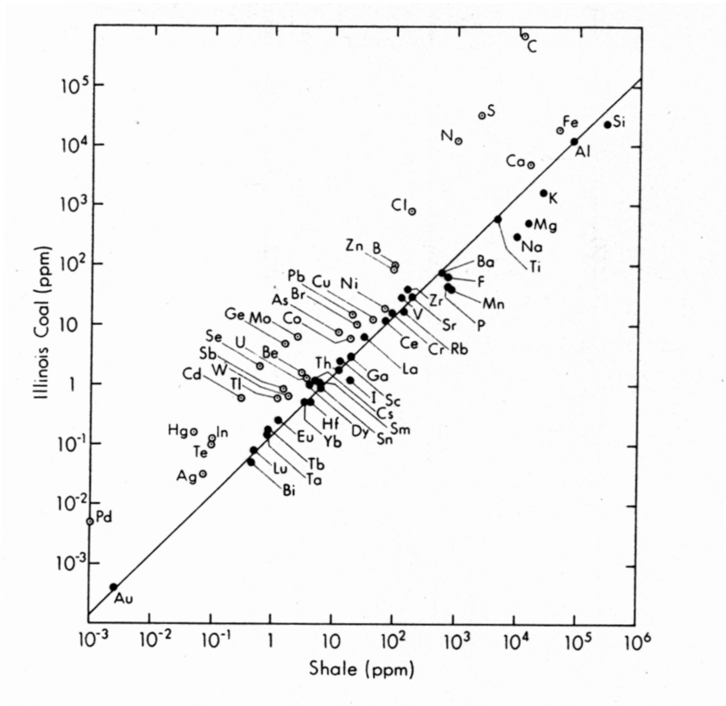

Figure 7 Plot of average shale and Illinois coal compositions. Open circles represent the elements with $E^i_{Al} > 2$ relative to shale.

biophile elements plus Be, Fe, Ge, and U are enriched in coal ($E^i_{Al} > 1$) and are associated mainly with sulfide and organic phases.

The compositions of average crude oils and Alberta crude oils are plotted against the shale composition in Figure 8. The elements nearest the dashed line (solid circles) in the figure have

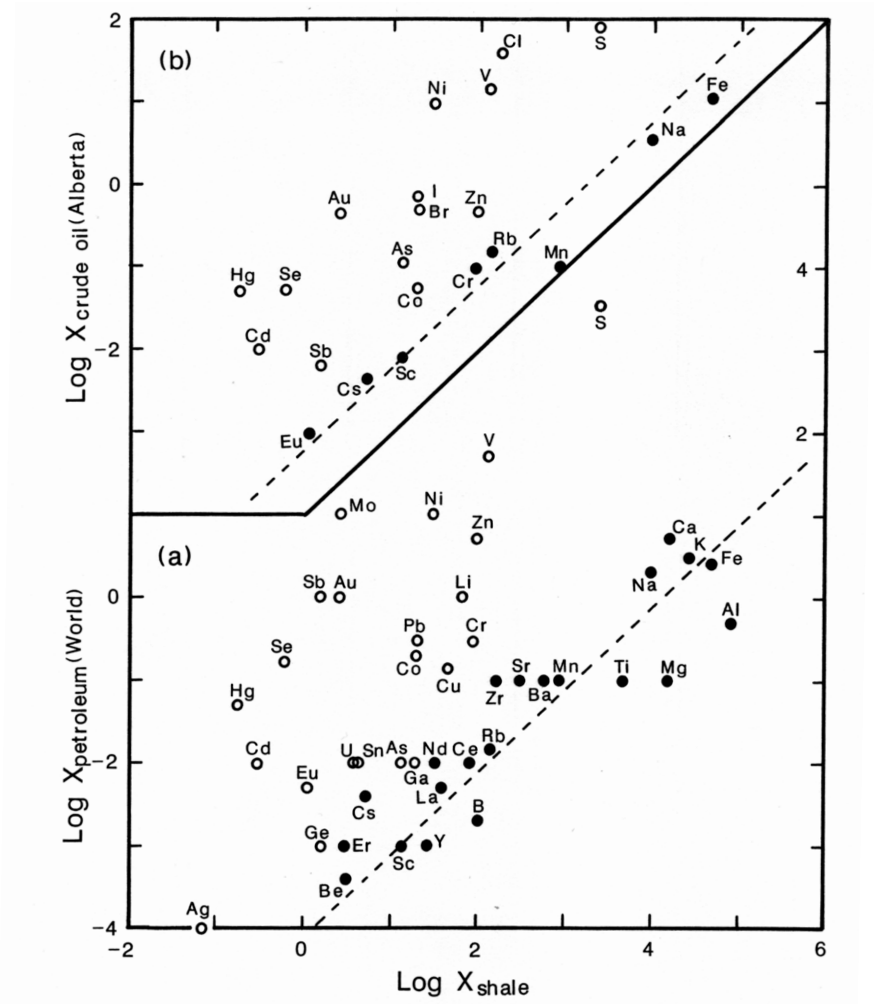

Figure 8 Plots of average shale versus (a) average petroleum, and (b) average Alberta crude oil compositions. Solid circles are elements with E^{i}_{Al} around one relative to shale.

E^{i}_{Sc} values of about 1 relative to shale. Therefore, these elements in crude oils are again mostly contributed by colloidal clay mineral particles. Other enriched elements (open circles with E^{i}_{Sc} of about 10 to 10^5) in crude oils probably exist as metallo-organic complexes.

Acknowledgement:

Many thanks to Professor Yoshiki Sohrin, who had graciously sponsored my visit to Kyoto University. The pioneering works on algae and seaweed by Professor Toshio Yamamoto are duly acknowledged here.

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