

Rainer Schimming

Theories on the Earth System. Vernadskij, Lovelock and beyond

Abstract

The theories of Vernadskij and Lovelock, similar to each other but with almost 50 years between them, are cornerstones in the formation of the earth sciences. In the present short note we discuss the two doctrines and contrast them with current concepts.

Introduction

The Russian-Soviet geochemist and universal thinker Vladimir Ivanovič Vernadskij (1863-1945) from 1926 on presented an interdisciplinary theory on the earth system and its subsystems which emphasized the role of life on the global scale, and about 50 years later the British biochemist James Ephraim Lovelock (born 1919) presented a similar theory. Both doctrines are built around the key notion biosphere or Gaia, respectively, which denotes the earth together with all the organisms on it. In a sense, Vernadskij anticipated Lovelock's ideas or, the other way round, Lovelock rediscovered Vernadskij's ideas.

Both the authors extended the biosphere or Gaia concept by taking into consideration man and his activities. Vernadskij introduced the notion noosphere, which means realm of reason.

Here we will focus on the innovatory power of the two theories and we will contrast them with a modern conceptual framework. For more details on the work and the life of the two classical authors we refer to the extensive literature.

Comeback of Gaia

James Lovelock elaborated his theory from 1972 on, partially assisted by the American biologist Lynn Margulis (1938-2011) (Lovelock, 1972, 1979,

1988, 2006; Lovelock and Margulis, 1974). He claims (or they claim) that life on the global scale

- not merely passively adapts (according to the biological evolution theory) to the conditions on earth, it moreover actively forms these conditions.
- thereby creates and maintains a favourable for itself environment; it makes the earth a better place for living.
- as a system together with its habitat, the earth, behaves like an organism. Namely, it has a kind of metabolism and it regulates its state through feedback mechanisms.

The organismic analogy instigated Lovelock to call the system earth + life "superorganism Gaia". This name was suggested to him by his colleague William Golding (Lovelock, 1972).

Remind that Gaia was the goddess of the earth in ancient Greece. Similar beliefs occurred in other cultures. Myths of mother earth were widespread in the past. The name with a tradition behind stimulated attention for Lovelock's doctrine, which then became known as Gaia theory or Gaia hypothesis. Other authors modified the meaning. The word "Gaia" in the literature after Lovelock may mean

- a synonym for "earth".
- the compound system earth + life.
- the latter interpreted as a superorganism or an organism.
- a being with spirit or even with a personality.

In particular, the quasi-religious movement New Age occupied "Gaia" and interpreted it within a pantheistic picture. Lovelock himself denied any religious or esoteric meaning, but he remained rather impassive towards such tendencies by others (Lovelock et al., 2001).

In our opinion

- it is convenient to have a proper name for the system earth + life.
- to call this an organism can be accepted only as a metaphor.
- any supernatural interpretation leaves science and becomes a matter of belief.

Counterarguments arose in the discussions of Lovelock's claims. In some respects Gaia behaves like an organism, in other respects it does not. It is known from biology that the parts (cells, tissues, organs, ...) of a genuine organism typically cooperate with each other. But the parts of Gaia (individuums, populations, species, ...) rather often compete with each other or are in an epistemic relation (where one part for its benefit harms the other part). It is known from palaeontology that Gaia sometimes deteriorated the conditions for living

(Walker, 2003). Metaphorically spoken, Gaia then became Medea, a destructive bitch. Peter Ward introduced the metaphor and discussed several Medea events in the history of our planet (Ward, 2009).

Repeated innovations

Lovelock's theory was not quite new. The Russian scientist V. I. Vernadskij much earlier had developed an analogous theory (Vernadskij 1926; Vernadskij 1929; Vernadsky 1945, 1998). Both authors initiated or promoted the following changes of the scientific picture of the earth.

1. From geographic regions to the whole globe, from organisms and ecosystems to the whole kingdom of life, from local to global ecology.
2. From the earth and life on it to a compound, named biosphere by Vernadskij and Gaia by Lovelock.
3. From geological sciences and life sciences to an integrative discipline, called biogeochemistry by Vernadskij, geophysiology by Lovelock.
4. From parallel evolutions of inanimate matter and life to a coevolution which is dominantly driven by life. The heightened role of life is the central claim of the two authors.
5. From an earth-bound to a planetary perspective. It turns out that life just causes the distinguishing features of the earth among the other planets.
6. Recognition of an analogy between an organism on the one hand and the biosphere or Gaia system on the other hand. In our opinion, this is a variant of system-theoretical thinking. System theory is implicit in Vernadskij's work; much later the notions system, input, output, feedback etc. were at disposal for Lovelock.

Vernadskij's biosphere concept became known mainly through a book just on this subject. His opus magnum originally appeared in Russian language in 1926 (Vernadskij, 1926) and already three years later in French (Vernadskij, 1929). An unabridged English edition appeared about 70 years later (Vernadsky, 1998). The theme was further elaborated by many papers. The word "biosphere" was coined by the Austrian geologist Eduard Suess (1831-1914), but with another meaning (Andreae, 2012).

Lovelock introduced Gaia in a short article in 1972, then in a paper in 1974 together with Lynn Margulis (Lovelock 1972; Lovelock and Margulis, 1974). Numerous articles and books followed.

Lovelock only with much delay became aware of Vernadskij's pioneering work. Later he acknowledged the predecessor, but he did not systematically compare the two doctrines (Lovelock, 1986).

Strata, scales, mankind

Let us present some conceptual framework for the theories which are discussed here and for other theories on the earth system.

The world exhibits a structure which can be described foremost in terms of space, time and complexity. There are, with increasing complexity, inorganic, organic and human substances, synonymously also called non-living, living and thinking substances. The German philosopher Nicolai Hartmann (1982-1950) is quite often cited in this context; he coined the name strata (in German: Schichten) for kinds of substance which are discerned by their grades of complexity (Hartmann, 1940). Each stratum (in German: Schicht) has several substrata. Hartmann and other authors elaborated a natural philosophy of strata and substrata.

Unconveniently, the first stratum is characterized as a negation of the second one, it is called inorganic, non-living, or inanimate. Vernadskij proposed a better name: inert matter. Unfortunately, the new term did not find general acceptance.

The inorganic stratum is ubiquitous and eternal, whereas the higher strata are restricted in space and time. According to current knowledge, the living and the thinking strata are confined to the planet earth and to proper time periods. Life appeared on earth about 3.5 billion years ago; this event divides the arrow of time into the azoicum (without life) and the zoicum (with life). The following revolutionary processes mark the evolution of mankind.

- a. Man entered the stage about 2 million years ago.
- b. History in a strict sense, i.e. with records of what had happened, began several thousands of years ago.
- c. At some time, the governance of nature over man was reversed; man became the dominating environmental factor. Vernadskij reflects this turn as the transformation of the biosphere (where life is the dominating factor) to the noosphere (Vernadsky, 1945). The chemist Paul Josef Crutzen (born 1933) introduced the notion anthropocene; it is defined as the era where dominantly man forms the face of the earth. The anthropocene comes after the holocene (Crutzen, 2012).
- d. Later, man's activities have run out of control and caused an environmental crisis, characterized by several global problems. Lovelock's Gaia metaphor is well suited to illustrate ecological problems (Lovelock, 2006).

Let us refer in the context of item d) just to two influential books: the one which triggered sensibility towards environmental problems, namely the first report to the Club of Rome (Meadows et al., 1972), and the most advanced proposal how to get out of the ecological crisis (Schellnhuber et al., 2011).

Basic concepts of natural philosophy take man as a point of reference. This is, in particular, the case for the basic notion of nature itself:

culture: = everything which is made by man,

nature: = the complement.

(There are some other meanings of the two terms, but we will not consider these here).

Man is also a reference point in the following triadism, a division of the real world with respect to space and time scales:

mesocosmos: = the world at the human scale,

macrocosmos: = the world at larger scales,

microcosmos: = the world at smaller scales.

The mesocosmos can be perceived by means of the unarmed human senses. Perception of the other scales needs instruments: the macrocosmos is typically observed by means of telescopes, the microcosmos is typically observed by means of microscopes.

Subsystems of the earth system

Here we discuss the structure of the earth system in modern terms. The total system is the planet earth including all matter on or around it. A classification of matter leads to a hierarchy of subsystems. Those are defined as "envelopes" of the naked planet; the words for the envelopes carry the suffix "sphere":

atmosphere: = air envelope,

hydrosphere: = water envelope,

cryosphere: = ice envelope,

lithosphere: = stone envelope,

pedosphere := soil envelope.

These inanimate systems together constitute the geosphere. The latter is the habitat of the two higher strata:

biosphere: = all life on earth,

anthroposphere: = man and his culture.

The geosphere, biosphere, and anthroposphere are studied by the geological sciences, life sciences, and humanities, respectively.

The geosphere and the biosphere together constitute the ecosphere, which is a synonym for the global environment of mankind. Finally, the ecosphere and the anthroposphere together constitute the earth system, the top of the hierarchy. The relation between the ecosphere and the anthroposphere is studied by human ecology.

The modern setting differs from the terminology of the classical authors. Vernadskij's biosphere and Lovelock's Gaia extensionally equal the ecosphere as defined here. Vernadskij's noosphere equals, again extensionally, the earth system. Intensionally, the terms do not coincide; the chosen words appeal on different aspects. In our opinion, anthroposphere (from Greek *Anthropos* = man) is a better name than noosphere (from Greek *nous* = reason), because – as we all know – not all human activities are reasonable.

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