MDAG.com Internet Case Study 70

MDAG-com Case Study 70 - A Graphical Depiction of Integrated Energy Balance, Interactions, and Contributing Mechanisms-Processes for Open Environmental Systems like Minesite Components, Version 1

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Abstract

Recent MDAG Case Studies have focussed on various forms of energy entering, flowing through, and exiting open-system minesite components like waste-rock piles and tailings impoundments. These varying forms and fluxes of energy are connected and affect each other. This is reflected in their creation of variable, but cyclical and periodic, aqueous concentrations and flows.

As the first attempt at depicting this graphically ("Version 1"), Figure 2-1 in this MDAG Case Study graphically shows the integrated energy balance, energy interactions as connected coiled "springs", and some contributing mechanisms and processes. Work continues on improving this graphical portrayal.

Table of Contents

1. Introduction

Recent MDAG Case Studies have focussed on various forms of energy entering, flowing through, and exiting open-system minesite components like waste-rock piles and tailings impoundments (Morin, 2020a, 2020b, and 2021a). These varying forms and fluxes of energy are reflected in their creation of variable, but cyclical and periodic, aqueous concentrations and flows (Morin, 2016, 2017a, 2017b, and 2018).

Morin (2020a) provided the following "Equation 2-2" as a general summary of this energy balance, using mathematical products of two "conjugate quantities" (Wikipedia, 2021a and 2021b):

$$E_t = TS + Vp + \sum \mu_i N_i + q\varphi + m\Psi + \tfrac{1}{2} mv^2 + \ldots \qquad \text{(Equation 2-2)}$$

where:

E_t = total energy, in joules
T = temperature, in Kelvin
S = entropy, in joules/K
V = volume, in meter^3
p = pressure, in pascal (joules/meter^3)
μ_i = chemical potential of the ith species, in joules/mole
N_i = number of moles (particles) of the ith species, in moles
φ = electrical potential in volts
q = electrical charge, in coulombs
Ψ = gravitation potential, in joules/kg
m = mass, in kg
v = velocity, in meter/second
(note: positive and negative signs can sometimes shift with parameter and methodology)

"Other terms can be added to Equation 2-2, such as radiation and biological energy. Therefore, Equation 2-2 is not exhaustive and complete."

To be generic, this Equation 2-2 did not include "d" (for differential or infinitesimal changes) in front of some variables as required by thermodynamics. This is because thermodynamics does not apply reliably to open systems like minesite components (Morin 2021b).

Morin (2020a) showed that simplifications of Equation 2-2 lead to common equations for physical groundwater flow, aqueous chemistry, and electrochemistry. Thus, Equation 2-2 and its energy balance are robust across "forms" of energy.

2. A Graphical Depiction of Integrated Energy Balance, Interactions, and Contributing Mechanisms and Processes, Version 1

Morin (2020a, 2020b, and 2021a) provided discussions of various mechanisms and processes that contribute to various forms of energy. Some examples are electrohydrodynamics, self potential, piezoelectricity, and galvanic reaction.

For minesite components with some ARD risk, galvanic reactions are attributed to differing types of sulphide minerals, where one sulphide mineral will oxidize relatively quickly while reducing the oxidation rate of the second mineral. This is often thought of as two sulphide minerals in physical contact. However, Wikipedia (2021c) clarified:

> *"The presence of an electrolyte and an electrical conducting path between the metals is essential for galvanic corrosion to occur."*

In other words, a connecting electrolyte (water with ions) must be present to consider this effect as "galvanic". In turn, this means the minerals do not have to be in physical contact and can even be relatively far apart.

This highlights the importance of water films on and around minerals (e.g., Ma et al., 2019 and submitted). The ionic contents of these water films could even reverse the oxidation sequence suggested by standard electrode potentials, as illustrated by the Nernst Equation.

By extension, humidity (water vapour in the gas phase) also plays an important role (e.g., Dy et al., accepted). This includes the intricate and underappreciated interactive way that aqueous concentrations in water films affect their own concentrations by interacting with adjacent humidity.

This MDAG Case Study is a first step (Version 1) in graphically portraying the integrated energy balance, energy interactions as connected coiled springs, and some contributing mechanisms and processes. This is depicted below in Figure 2-1. Work continues on improving this graphical portrayal.

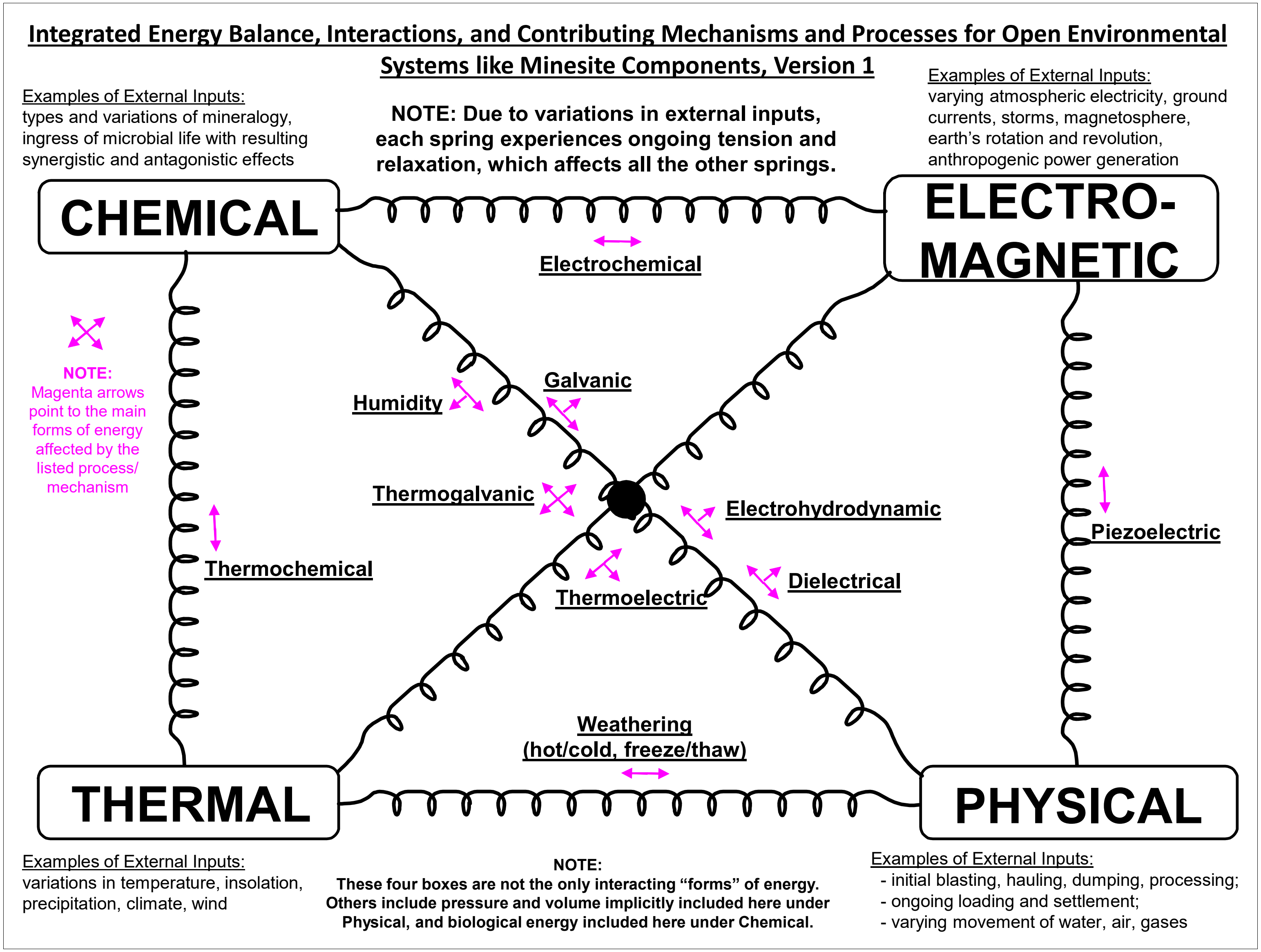

Figure 2-1. Version 1 of the integrated energy balance, interactions, and contributing mechanisms and processes for open environmental systems like minesite components.

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