Potential role of soil calcium and phosphorus on Galápagos tortoise growth

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1. Introduction

One of the most recognized symbols of the Galápagos is the tortoise. Their size and diversity are probably unrivaled. Indeed they served as one of the outstanding examples in the development of Darwin's Theory of Evolution. It is interesting to note that the vice-governor of the Galápagos once said that he could identify the island from which a tortoise came by its appearance.

The purpose of this poster.

- This poster builds on the vice-governor's obviously deep knowledge of the Islands and the tortoises.
- This poster does not present a body of completed research, nor does it present new data, nor does it present new methods of observation, data collection, or analysis.
- This poster calls existing observations or conclusions into question and it proposes a different perspective or interpretation of the existing data.
- Our purpose, thus, is to pose a question, provoke some discussion, and start a dialog. We encourage communication with any of the authors of this poster – including the following:

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2.Objectives of the Poster

1. Review previous research and observations
2. Speculate on several issues related to tortoise size in relation to conditions of the various Galápagos islands.
3. Examine the relationships among the tortoises, the geology, the soils and the vegetation of the Galápagos islands.

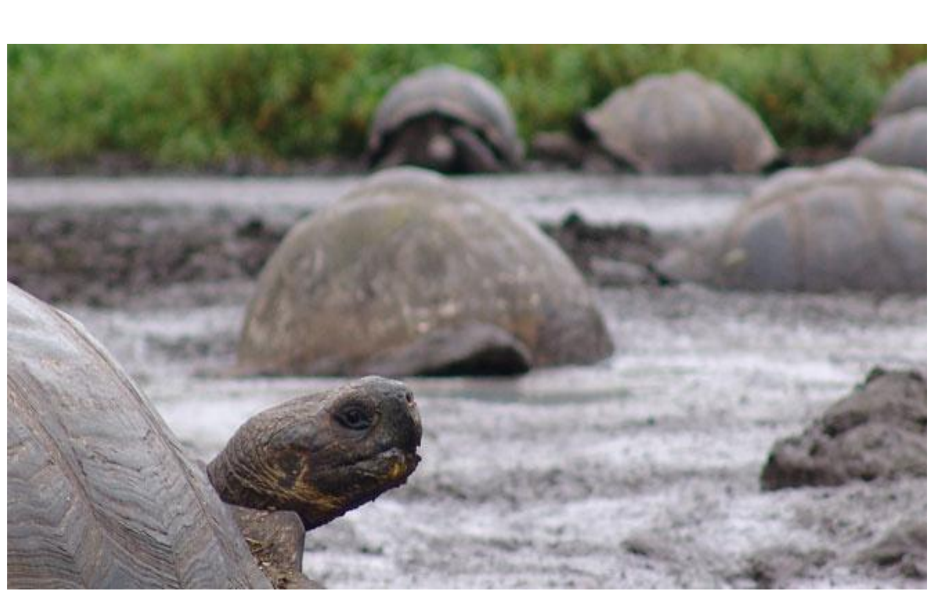

Figure 1. Galápagos tortoises. Photo Courtesy (Galápagos Online: http://www.galapagosonline.com/nathistory/wildlife/animals/tortoise.htm)

3. Evidence – Calcium Requirements of the Tortoise

3.1. Calcium availability and reproduction in animals

Birds

- Egg defects reported in birds (Graveland, 1995). Tit (*Parus major)* eggs on poor soils in Sweden had defects (Carlsson, 1991).
- Reproduction of passerines was limited due to calcium (Graveland and Drent, 1997).
- Birds adapt by reducing the size and number of eggs, according to the above authors.
- In response to decreases in calcium, birds may increase their search for Ca rich plants (Graveland and Berends, 1997).

Tortoises

- Desert tortoises (*Gopherus agassizii*) in California located and consumed soil from "mine" sites that contained significantly higher levels of calcium than surrounding soil Marlow and Tollestrup (1982) – "geophagy"
- Tortoises in captivity required Ca supplements to maintain normal growth and health (Pritchard, 1979).

Tortoises (continued)

- Tortoises seek out high calcium soils (Marlow and Tollestrop, 1982).
- Sought out locations contained high calcium (Ca): averaging 14200 mg kg^{-1} in contrast to the surface soils of 5028 mg kg^{-1} Ca. (Figure 2.)
- Bone density of tortoise females decrease in aquatic turtles at the time of egg development (Edgren, 1960)
- Tortoises have a higher Ca requirement due to the high amount of bone tissue.
- Cactus (*Opuntia*), a common food of tortoises, contains a surprisingly high 7.56 and 10.6% Ca (Nefzaoui and Salem, 2011).

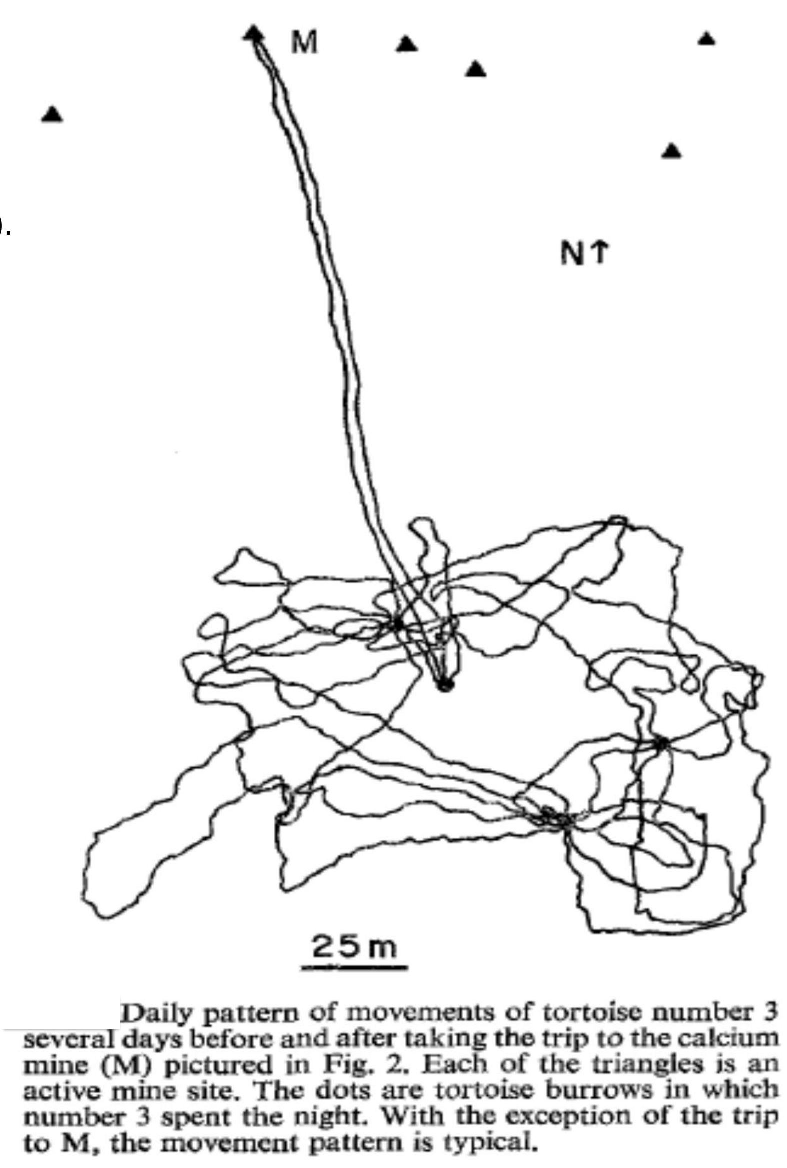

Figure 2. Tortoise daily pattern of movement (Marlow and Tollestrup, 1982).

4. Evidence – Soils of Galápagos

4.1 Approximate elevation of the Islands

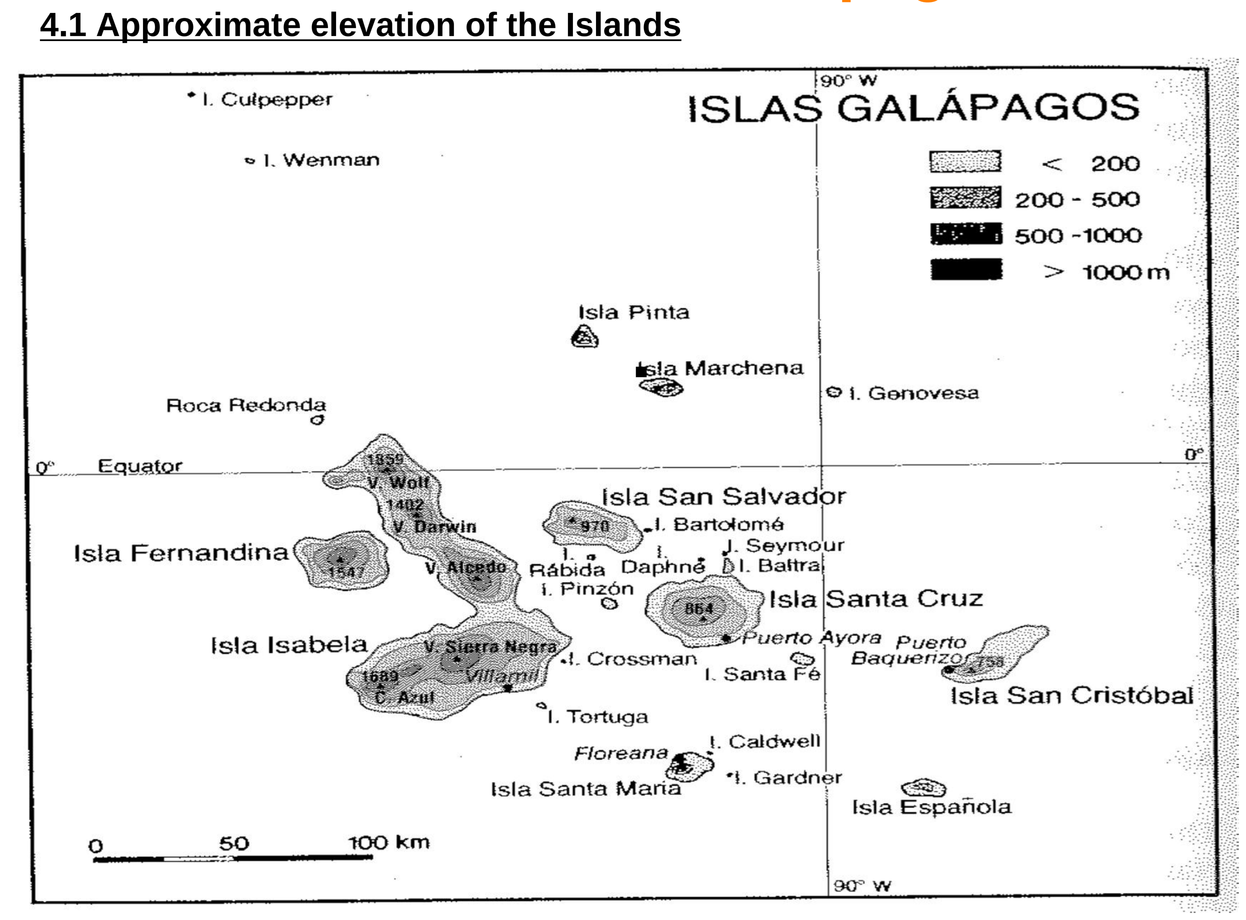

Figure 3. Elevation of the Islands of the Galápagos (Franz, 1980).

4.2 Existence of red soils

- 'Red soils' are found on several of the older, eastern islands such as Baltra, Santa Fe, Española and in high elevations on the other islands (Franz el al. 1980),(Figure 3).
- High elevation soils (> 350m) were more highly weathered (Adelinet et al 2008; Ingala 1989), probably a result of the accelerated leaching (Figure 4).
- Ingala classified soils of the Great Groups Lithic Dystrandepts, Oxic Dystropepts, Rhodudalfs, as examples of weathered, low calcium soils at elevations higher than 350m. Only in some cases on Santa Cruz were soils such as the high Ca Argiudolls found at elevations higher than 350 masl.
- No reports give measured levels of soil Ca or P , i.e. levels of soluble, exchangeable or total calcium or phosphorus.
- 'Red soils' are typically the result of extensive chemical weathering i.e. reddish colors resulting from crystalline iron oxides remaining after chemical weathering of soils (Buol et al., 1989). Such intensive weathering strongly suggests low levels of nutrients and bases such as Ca.

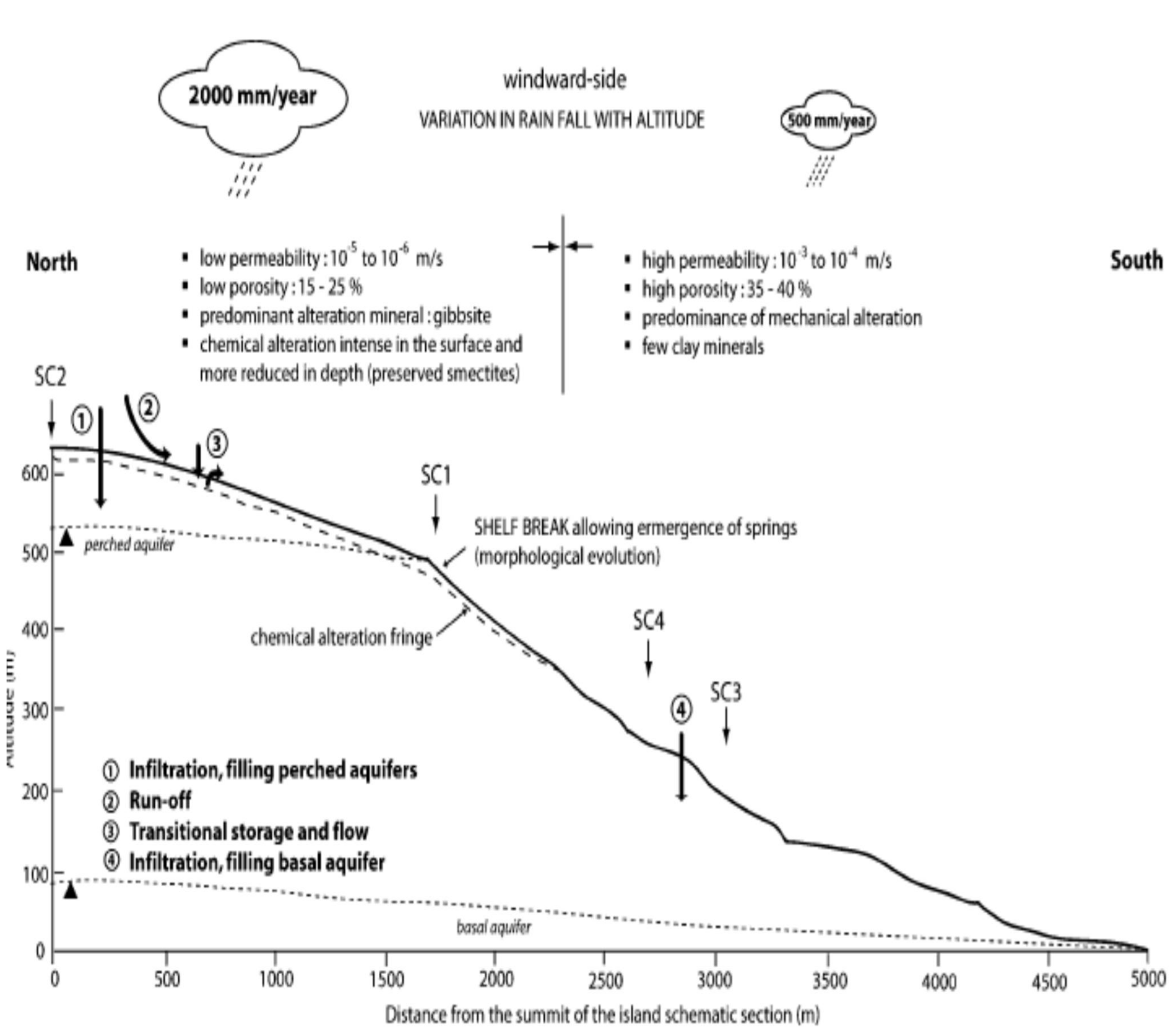

Figure 4. Hydrology of San Cristobal (Adelinet et al, 2008)

5. Tortoises of the Galápagos

5.1 Galápagos tortoises show marked variation in ecology and morphology across the archipelago.

- Can one, indeed, tell which island a tortoise came from simply by looking at them?
- Recent evidence suggests considerable genetic variability both between and within islands.
- Saddle-backed tortoises are usually found on the more arid islands, while domed tortoises occur on islands with extensive humid highlands.
- Tortoises of the older islands such as Española are some of the smallest (1)

6. Speculation:

- Given: calcium and phosphorus influence tortoise growth, morphology and movement patterns.
- Given: Tortoises require large amounts of usable calcium for growth and, in particular, shell and egg formation.
- Given: Small saddle-backed tortoises have markedly small, fragile shells relative to their domed cousins, and their presence occurs on old low-lying islands.
- Might one of the causes of variation in Galápagos tortoise size be the level of soil calcium and phosphorus in the soil and vegetation growing there?

7. Hypothesis: Nutrients such as calcium and phosphorus limit tortoise growth

8. Testing the hypothesis ?

1. Measures of soil calcium, magnesium and other bases are needed of tortoise habitat.
2. A multivariate assessment of soil Ca levels and tortoise growth at similar ages on the Islands of Pinta and Española. A report by Caccone et al. (1999) indicates that tortoises on these two islands are genetically very similar, thus reducing genetic adaptation as a possible source of growth differences.

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