Do exist different volcanic island hydrogeological conceptual models?

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Contents
One conceptual model, several realizations
Components
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Origins of volcanic activity

Source: US Geological Survey
Preliminary considerations

- Conceptual hydrogeological models
  - understanding of **groundwater** existence and functioning
  - explanation of **quantity** and **quality** of groundwater

Different points of view
- Geothermalism and volcanic risk not considered here
- Focus on **water resources** for
  - human supply, irrigation, tourism and trade
  - Ecosystem functioning and maintaining its services

The **Canary Islands** → important **source of knowledge**
- water works (wells and water galleries) **penetrate deep** into the volcanic formations → some of them can be visited
- erosion cut deep gullies
- slides create high **exposed bare walls**
- the semiarid to arid climate allows **direct land observation**
Aquifers → local designations
- Basal
- Dike impounded
- Perched
Hydrogeologic idealization of a single shield volcanic island. Inspired in Gran Canaria Island

One main island aquifer
Heterogeneity controlled by structure and age
Perched aquifers if enough recharge
Possible local semi-isolated aquifers
Variable behaviour of coastal area aquifers

Gran Canaria
Chloride, mg L⁻¹, near water table: main g.-w. body
max. altitude 1985 m

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General comments

Commonly mentioned volcanic island hydrogeological “conceptual models”: Hawaiian (Oahu), Canarian (Gran Canaria), of small islands: La Réunion, Stromboli, Sao Miguel/Terceira, Madeira, of medium size islands: Java, Etna, Island

Are they hydrogeologically different → No

They are cases under particular, unique circumstances
→ combining different factors and elements
→ involving one or several closeby volcanoes
→ with / without a geologically different basement

Differences are often the result of insufficient data and biased interpretation
Further general comments

- Each case is a unique combination of factors:
  - Geological-hydrogeological
  - Climatic
  - Morphologic
  - On data availability and underground accessibility
  - On socio-economic and legal conditions

Comparisons should be based on different factors
  - morphology and geology are not enough
  - may mislead
  - carefully combined
Complementary general comments

Even for a whole island single groundwater body → particular situations can be singled out

Basal and dike-impounded groundwater are:
→ mostly a non-needed description
→ manifestations of a single groundwater body

Perched aquifers may exist in areas with high recharge and very low permeability formations
→ but small discharge variability may be indicate manifestations of the island water table
Important effect of climate spatial distribution and variations
Rainfall + snow precipitation + snowmelt greatly affect recharge
Volcanic cores may be key elements. Often they are not easily observable.

Deep erosion and large landslides may unearth islands’ volcanic cores.

Dikes and intrusions in the core of a volcanic massif.
North front of the Caldera de Taburiente, La Palma Island, Canary Islands.

Foto EC 2014
Easter Island, Chile

High core
Only coastal aquifer

Intermediate core
More extensive coastal aquifer

Low core
Whole island aquifer

(Herrera y Custodio, 2007)

This is the actual case after MT surveys

In isolated volcanoes the core may be poorly developed

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La Réunion Island

High recharge, low permeability core, large landslides
→ high altitude large springs

Descloitres et al. 1997 WRR
Volcanic islands may rest on other geological basement formations

Small island
Jeju Island, Korea

Large island in a volcanic arc
Bandung-Bangor area, Sumatra
Las Cañadas del Teide, Tenerife, Canary Islands

Marrero, 2010
Volcanic core, cover and coastal belt of recent lava fields
Magnetotelluric survey of two transects in the Galápagos volcanic archipelago
Conclusions: Relevant macroscopic hydrogeological genetic considerations for small volcanic islands

**Causes**
- effusión of differencedated mantle materials
- crustal rock fusion
- mixtures and further differenciation

**Sites**
- rifts (plate splitting)
- transforming faults
- hot sport areas
- subduction strips (island arcs)

**Sites**
- in islands
- interlayered in sediments
- along lineations
- large effusions

**Age effects**
- Recent, modern, old
- Fresh, altered, thermally and chemically metamorphosed

**Materials:** basic, intermediate, acid composition

**Mode of deposition and effusion**
- Solids → pyroclasts, tephra → tuff
- Liquids → lavas
- Fluidized mass → ignimbrites, tuff
- Gases → mostly H2O and CO2

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Conclusions: Relevant macroscopic features of small volcanic islands

Characteristics change with distance $\rightarrow$ presence intrusives and pyroclasts

Deposits adapt and flatten the relief

Structures to be considered:

- Massive flows
  - lavas
  - ignimbrites

- Piling of pyroclasts and ash (tuff)

- Intrusive bodies: dikes, others

- Calderas and collapse forms

- Big slides and lahars

Alteration by:

- weathering
- groundwater
- gases, temperature, hydrothermal

Ageing reduces

- permeability
- porosity
- drainable porosity

$\rightarrow$ There is no simple relationship
Conclusions: Specific properties of volcanic rocks to define their hydrogeological conceptual model

- Highly heterogeneous in detail, → large scale hydrogeological units can be defined

- Medium drainable regional porosity

-- Generally, low permeability, except for recent, unaltered saturated formations

- Significant average permeability and porosity down to deep depths

-- Dikes play a controversial role → barrier or drain → contribute to anisotropy

- Fracturing and tectonics are important, → difficult to know → variable and controversial role

-- A low permeability volcanic core is not always well-developed above sea level

-- Inland young volcanics may be unsaturated, but are important recharge areas

-- Coastal young volcanics are often naturally seawater intruded → sometimes confined
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Thanks for your attention