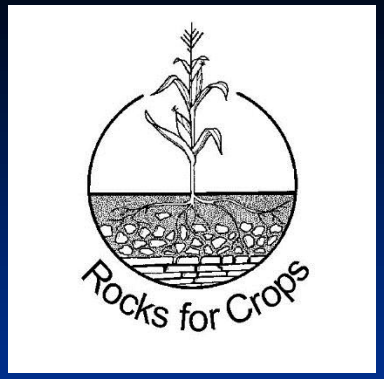



# ‘Rocks for Crops’ in the world

Peter van Straaten

University of Guelph,

Canada

# Outline

- Introduction: Agrogeology and Rocks for Crops
- Focus on multi-nutrient, multi-mineralic silicates – 'Rochagem'
- Experiences from various countries in the world
- Outlook

# What is agrogeology?

There are two aspects of agrogeology:

1. Influence of parent material on soil development and soil fertility

2. Beneficial application of rocks and minerals to enhance productivity of soils: ROCKS FOR CROPS

# Rocks for Crops

**The term 'Rocks for Crops' in English was used for the first time in 2002 (van Straaten 2002)**

**Most work on use of single nutrient rock application e.g. phosphates, K-rocks, liming materials,**

**Today:**

Focus on multi-nutrient, multi-mineralic silicate rocks (Rochagem)

# Understanding the fundamentals: Factors influencing the dissolution of silicate rocks

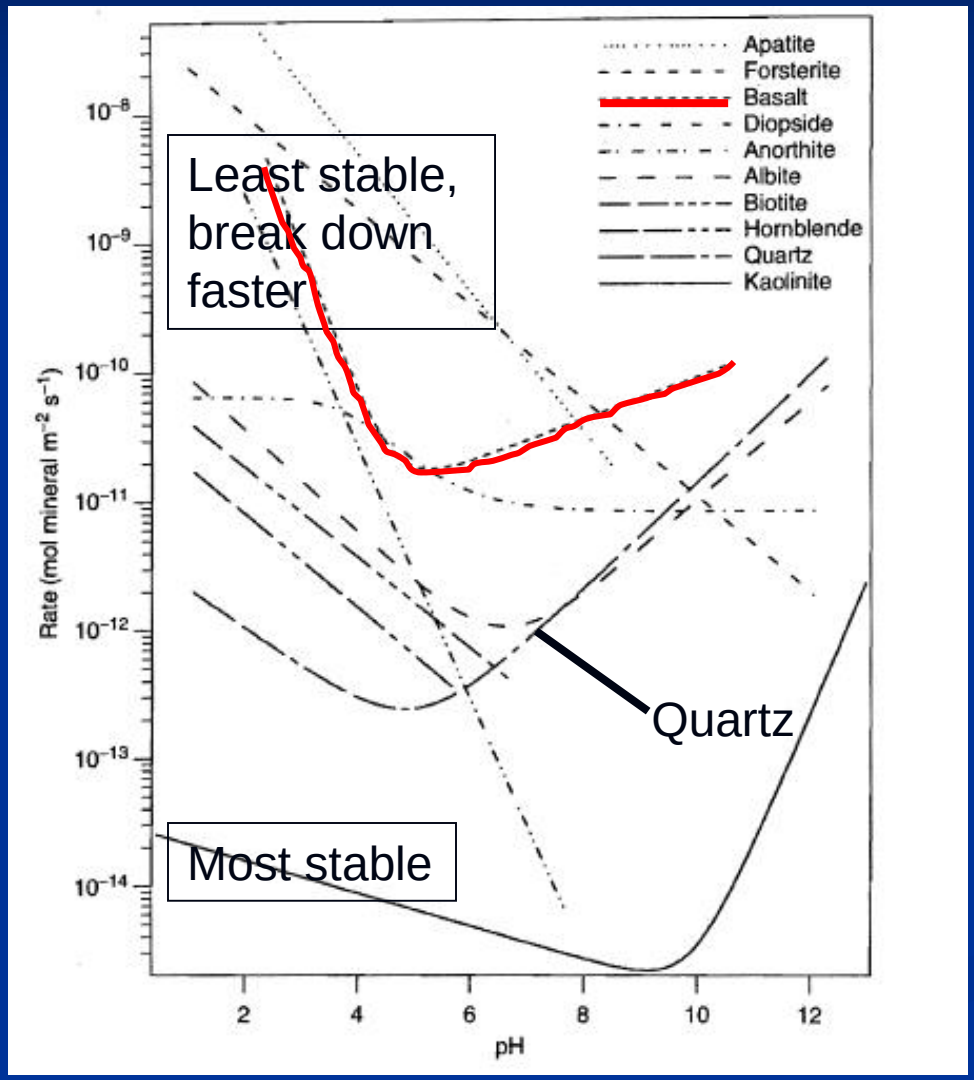
*Nutrient Cycling in Agroecosystems* **56:** 11–36, 2000.



**Factors influencing the release of plant nutrient elements from silicate rock powders: a geochemical overview**

A.D. Harley* & R.J. Gilkes
*Soil Science and Plant Nutrition, Faculty of Agriculture, University of Western Australia, Nedlands, Western Australia 6009, Australia (*Corresponding author: e-mail: aharley@cyllene.uwa.edu.au)*

# Understanding the fundamentals:
## Factors that influence mineral dissolution rates




Source: Brantley 2008

Grain size (surface area)

Temperature

pH in soil solution

pH and complexation effects of organic compounds

microorganisms, mycorrhizae enhance mineral breakdown

# Understanding the fundamentals: Dissolution rates of selected K silicate minerals

| Mineral | Mineral family | Formula | Weight % K | Weight % $K_2O$ | Dissolution rate (acid mechanism), log mol $m^{-2}$ $s^{-1}$ |
|---|---|---|---|---|---|
| Potassium feldspar | Feldspar | $KAlSi_3O_8$ | 14.0 | 16.9 | -10.06 |
| Leucite | Feldspathoid | $KAlSi_2O_6$ | 17.9 | 21.6 | **-6.00** |
| Nepheline | Feldspathoid | (**Na**,K)$AlSiO_4$ | 8.3 | 10.0 | **-2.73** |
| Muscovite | Mica | $KAl_3Si_3O_{10}(OH)_2$ | 9.0 | 10.9 | -11.85 |
| Biotite | Mica | $K(Mg,Fe)_3AlSi_3O_{10}(F,OH)_2$ | 9.02 | 10.86 | -9.84 |
| Phlogopite | Mica | $KMg_3(SiAl)O_{10}(F,OH)_2$ | 9.33 | 11.23 | -10.00 |
| Glauconite | Mica | $(K,Na)(Fe^{3+},Al,Mg)_2(Si,Al)_4O_{10}(OH)_2$ | 5.49 | 6.62 | **-4.80** |

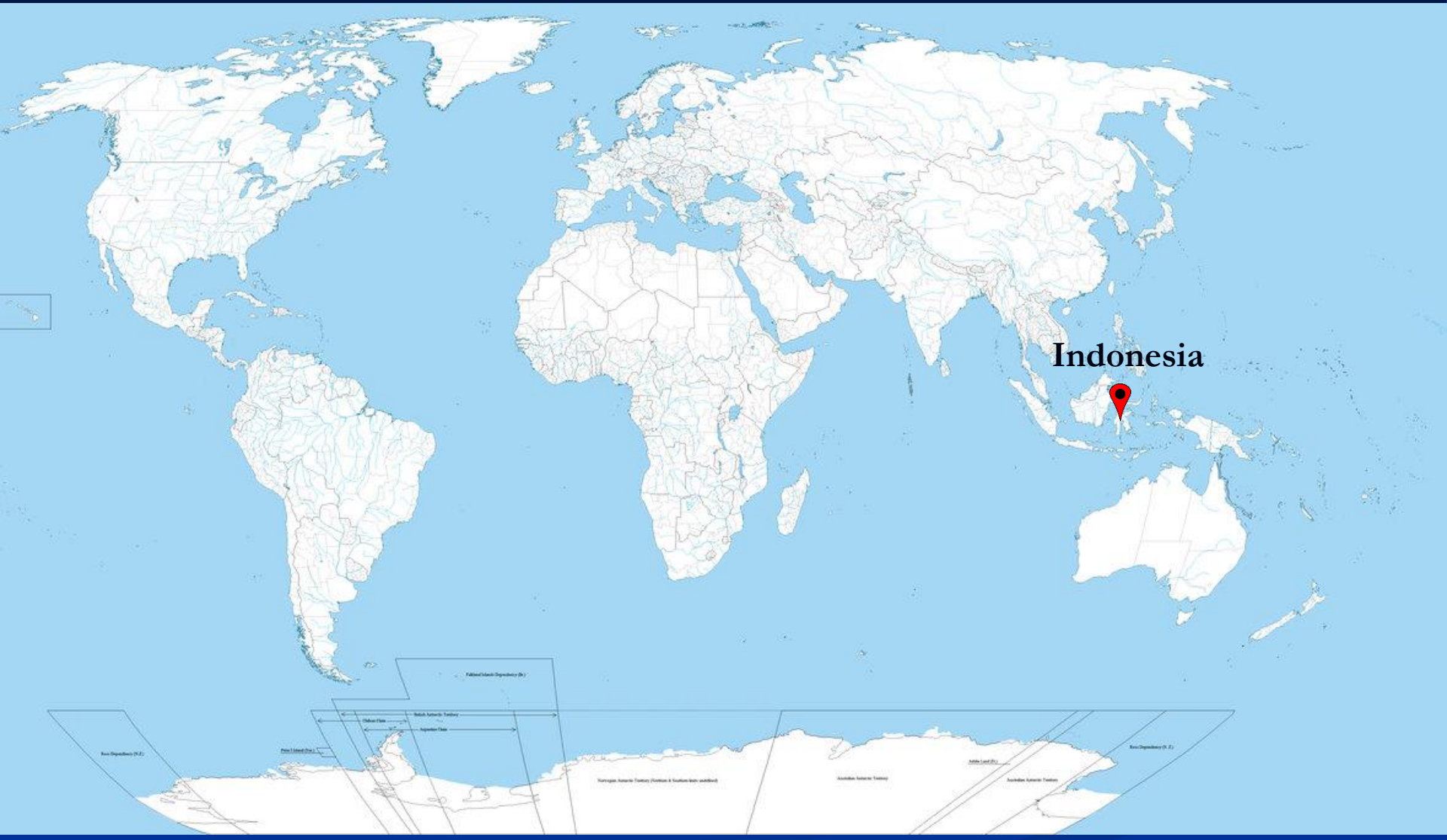
Source: Palandri and Kharaka, 2004, USGS

# Rocks for Crops research and development in the world

# Asia

- India – Composting and K and Si research
- China – Agrogeological/geochemical mapping
- Indonesia – K-Si research

# Agrogeological work in Indonesia



# Agrogeological work in Indonesia

## 2 Groups:

- K-silicate research: Geological Survey, Tekmira/Bandung and University of Padjadjaran

  **Bayu Sayekti (2015): MSc thesis**

- Si-research 'Healthy Farming', Rock processing: University of Lombok, Professor Joko Priyono

# K-rich silicate rocks in Indonesia's Sunda arc, active converging plate margin

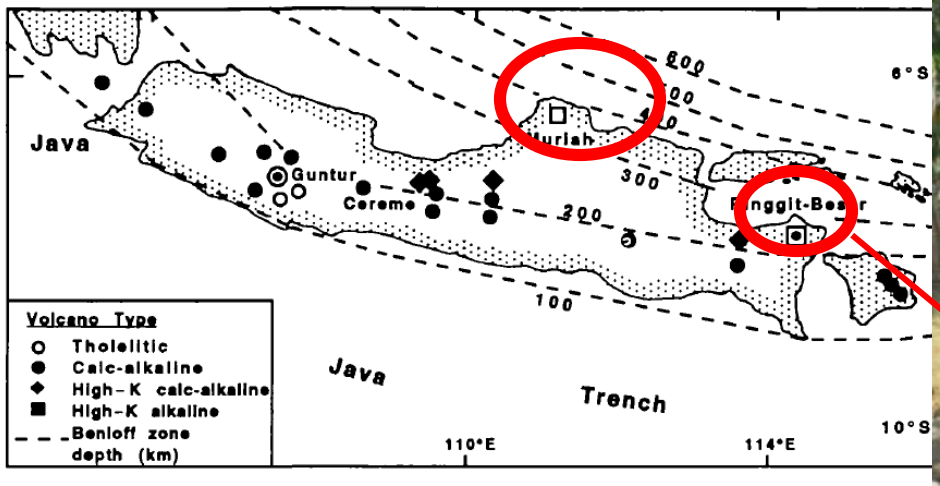
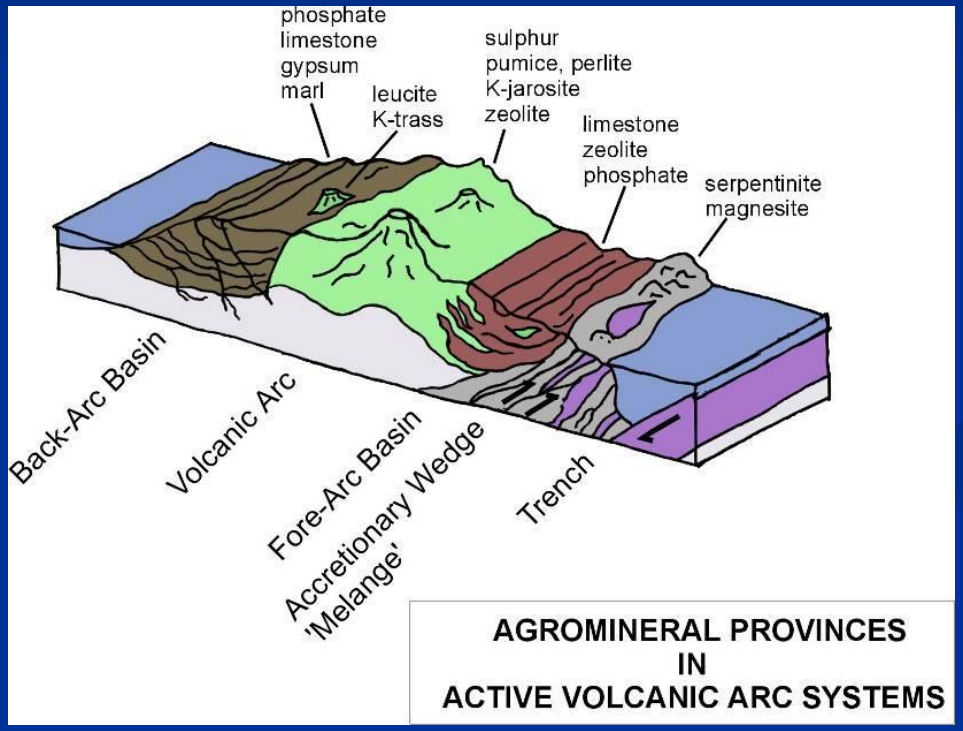



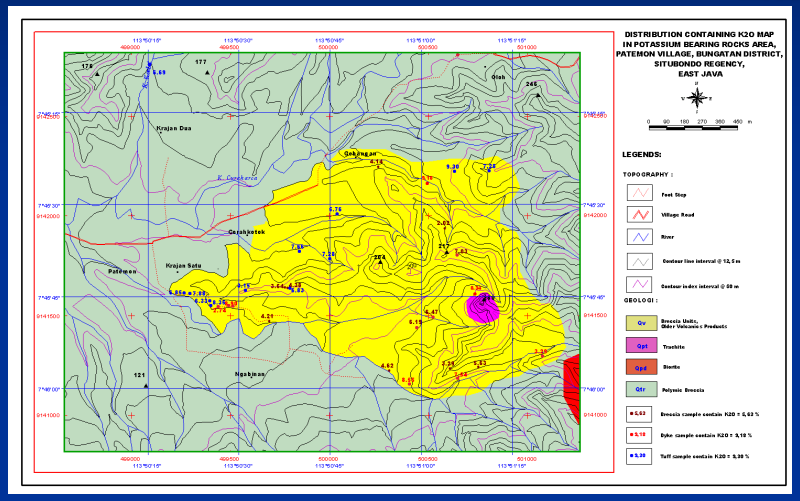

FIG. 1. Map of Java, indicating the location of Ringgit–Beser and the contours for the depth to the Benioff zor
(Hamilton, 1979).

Source: Edwards *et al* 1994

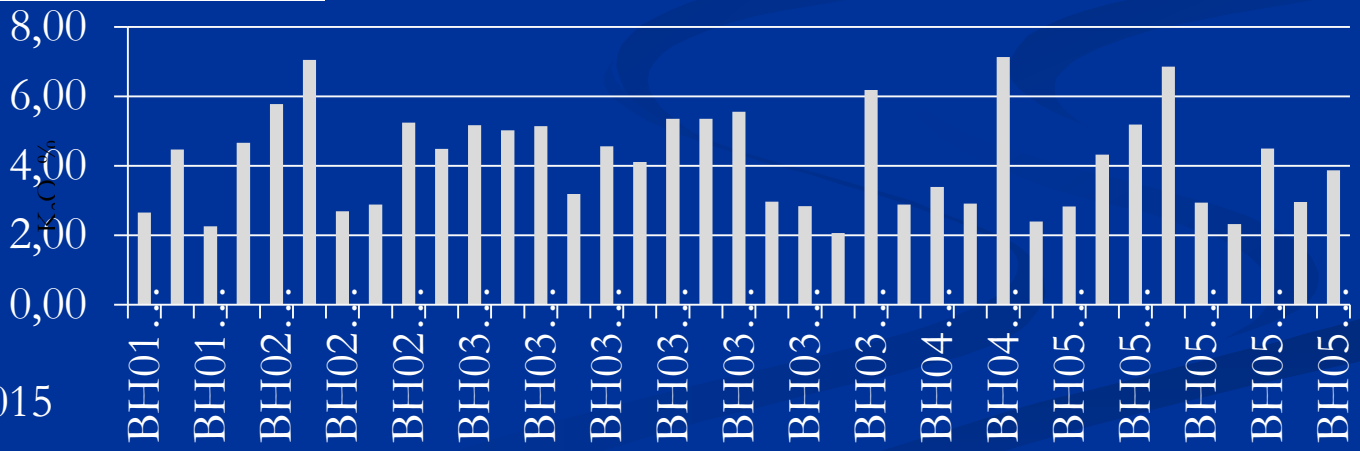
# Collaborative research work with Geological Survey of Indonesia (Kusdarto and Sayekti) and PvS




# $K_2O$ content in boreholes at Ringgit Beser complex, Situbondo, East Java, Indonesia

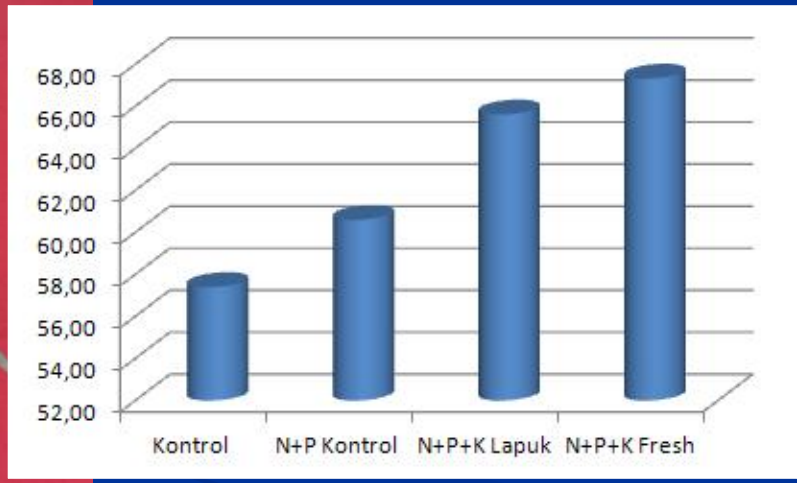



Large volume, low grade




Source: Sayekti 2015

# Pot trials with direct application of K-rich rock from Situbondo, Java: Soybean trial 49 days after planting




Source: Sayekti 2015

# Further processing?

2% citric acid extractable K and Si from rocks of Indonesia

| Sample | K (mg/kg) | Si (mg/L) |
|---|---|---|
| Ringgit BH | 679 | 1306 |
| Ringgit 3 (leucite bearing) | 8970 | 7900 |
| Muriah | 740 | 1570 |
| Sulawesi | 2516 | 5797 |

Little interest in large scale, direct application: mining, economics?

Interest for local application on sugar cane (K-Si),

Interest to develop Organo-mineral product: BIO-K

Interest to develop liquid 'Si-K rock extract' product

# Multi-cultural collaboration with Lombok University, Indonesia

# Research by Prof. Joko Priyono


Plus neem extract

'Liquid' rock extract

# Application of silicate rock extract to rice paddies

- Successful foliar application of Silicate Rock extract on rice paddies in salt affected areas of Sumbawa, Indonesia

# Example of transforming rocks into crops

Enhanced rice production and rice resilience through increased application of Silicon, liquid extracted from locally available rocks

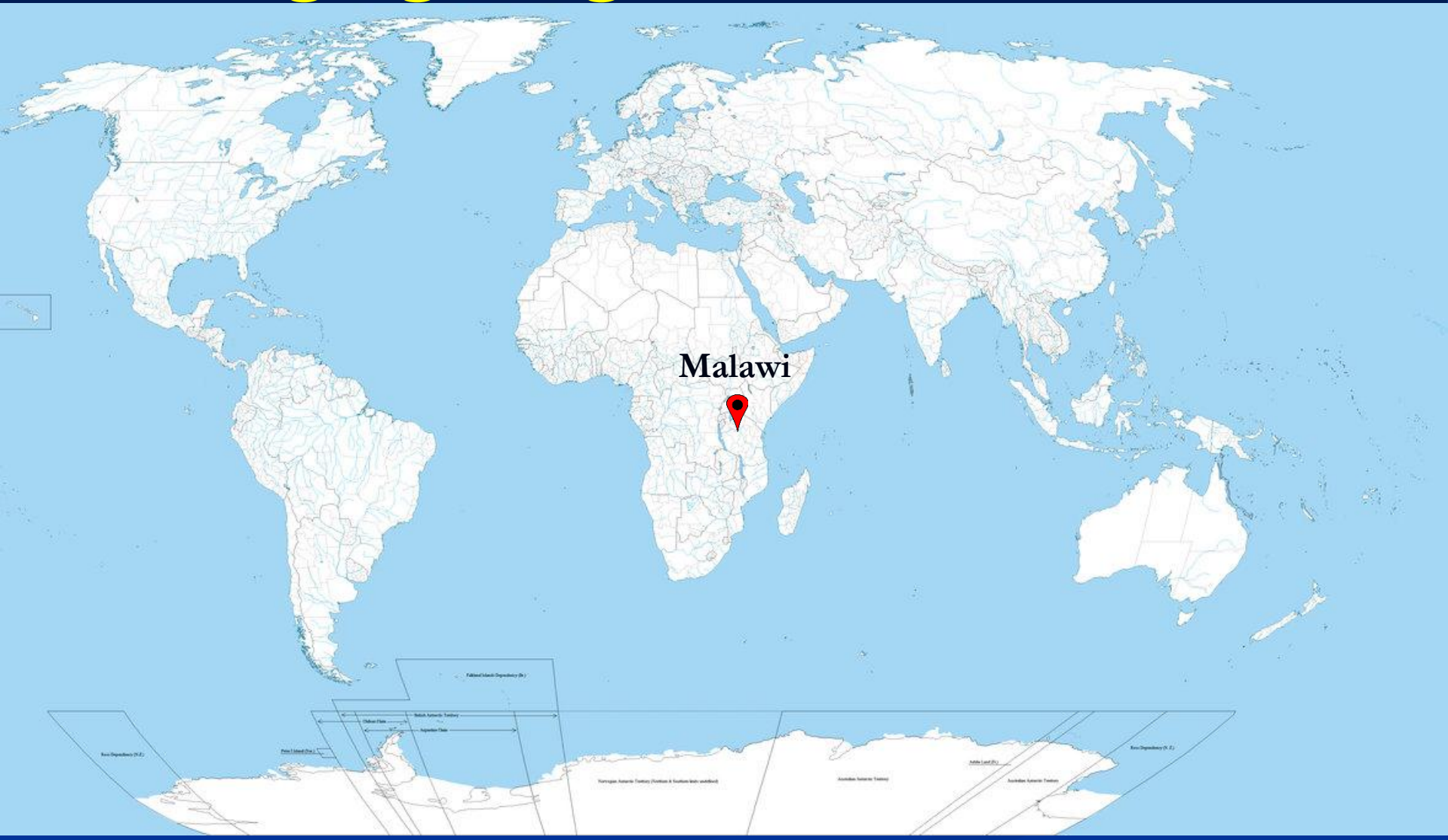
# Rocks for Crops research in Indonesia: Opportunities and Barriers

- **Opportunities**:
  - Favourable agrogeological setting (active converging plate margin) for multi-mineralic-silicate research
  - Active groups of geologists and soil scientists
  - Innovative 'Healthy Farming' research
  - New directions of rock processing
- **Barriers:**
  - Lack of Funding
  - Lack of opportunities to collaborate with international groups

# Rocks for Crops research and development in Africa

- Active research:
  - Malawi
  - Uganda
  - Cameroon

# Agrogeological work in Malawi

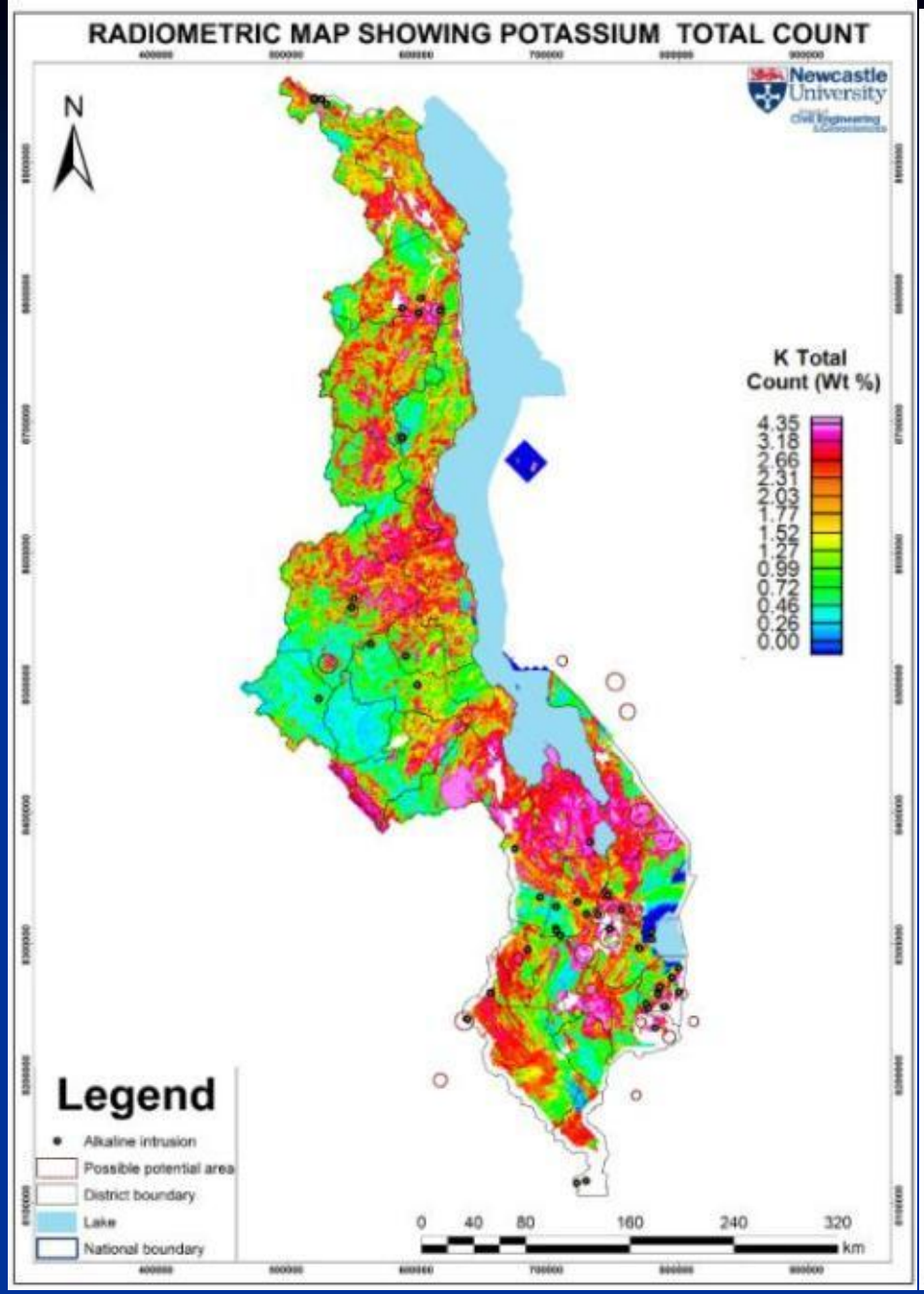


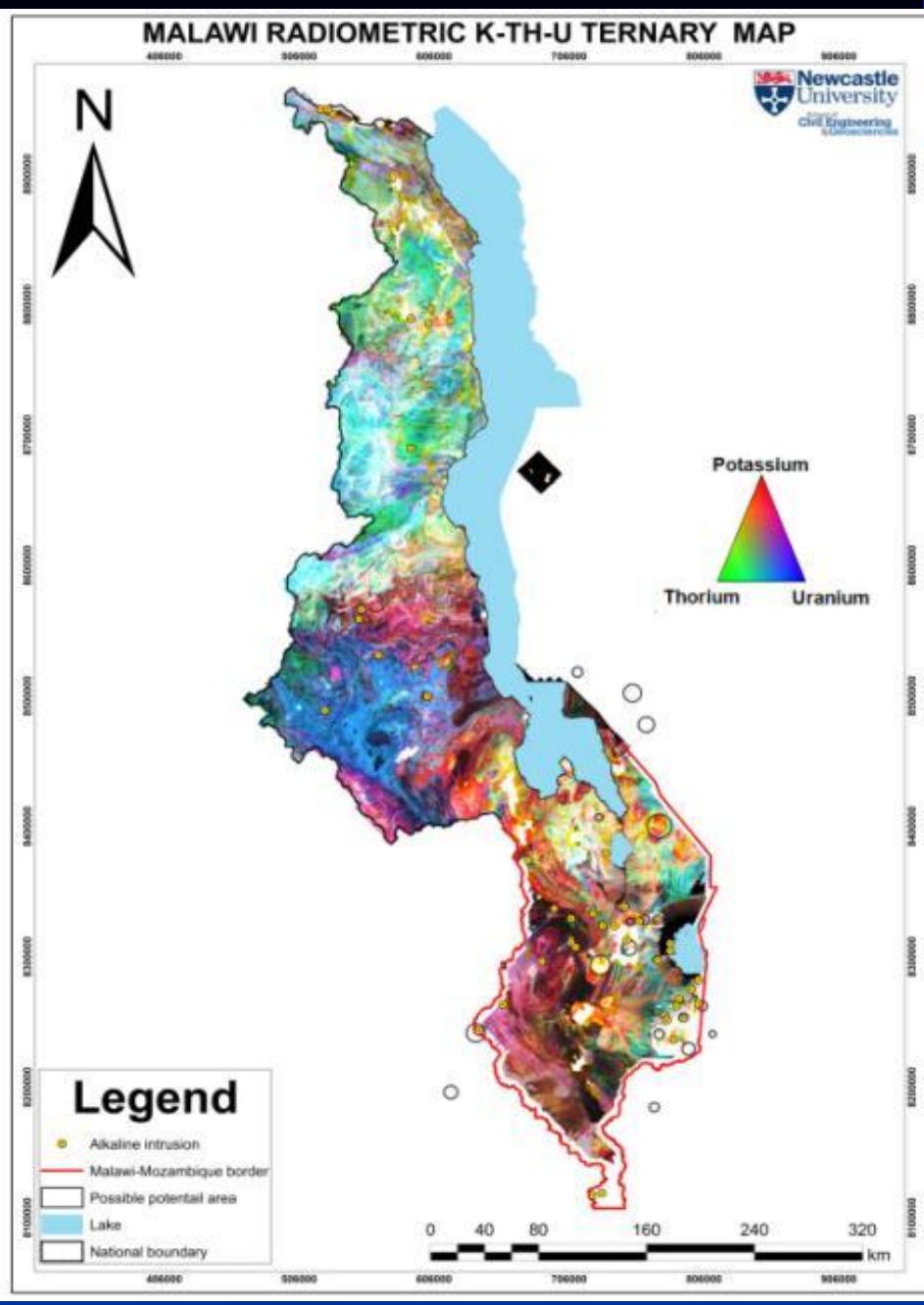
# Work by A. Chiwona (Malawi), currently Newcastle University, UK:

## *Focus on nepheline syenite*

- Presentation: Novel potash fertiliser from nepheline syenite for Africa's agricultural growth
- Presentation: Extending the reach of crushed-rock fertilizer to Africa
- Use of geophysical methods to delineate potential agromineral resources in Malawi

A. Chiwona




Source: Chiwona *et al*. 2016)

Next steps: Ground trothing, rock characterization, K release studies, plant growth experiments

# Rocks for Crops research in Cameroon


# Rocks for Crops research in Cameroon

- 2 active agrogeology Groups:
  - Jean-Pierre Tchouankoue et al.
  - Samuel Tesopgang et al.

**Opportunities:**

Geotectonic setting: Cameroon volcanic line in Precambrian terrain (with poor soils)

Active geological group

Resource-poor farmers using garden agriculture

**Barriers:** Lack of Funding

# Rocks for Crops research in Uganda

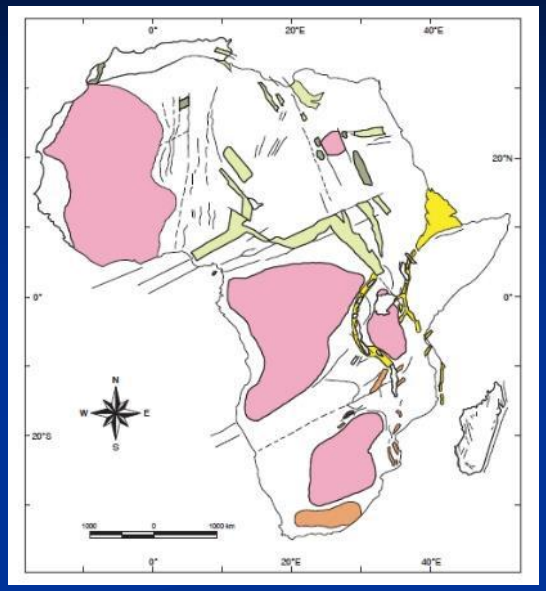
# Rocks for Crops in Uganda

- 'Kamafugite' research for banana and coffee cropping (geochemical, soil science and agronomic studies)
- Vermiculite processing and organo-mineral blending project, product development (Nathan Wanda)

- Agrogeology Association of Uganda

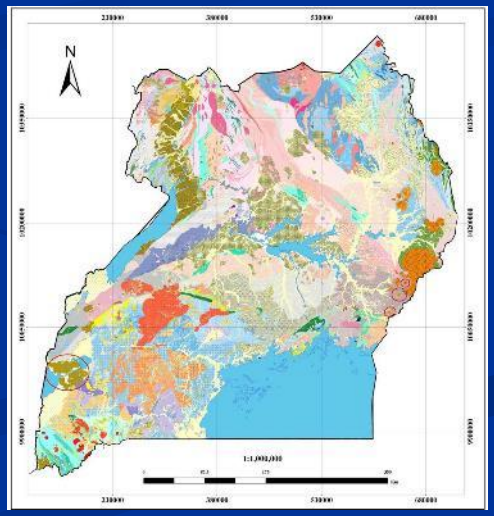
# Kamafugite research and development

- Resource assessment (geochemical and mineralogical studies in W-Uganda) – agromineral province: **RIFT**



Volcanic crater lake,
Lake Katunga (Katungite) -Ka

Volcanic crater lake,
Lake Mafuro (Mafurite) - maf



Uganda (ug)

= Ka – maf - ugite

# Multi-nutrient Kamafugites in W-Uganda

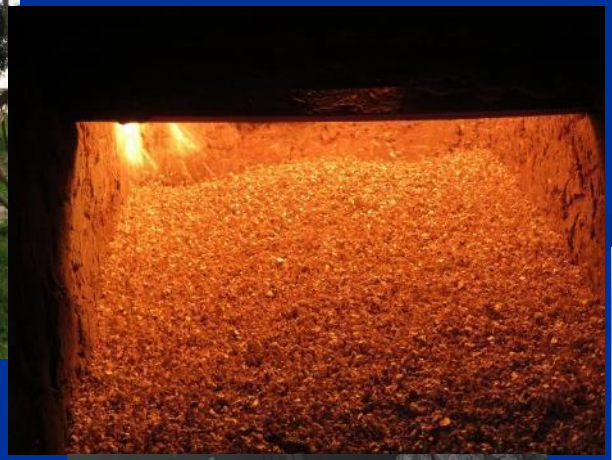
- Ultra-potassic ultra-mafic rocks, leucite and kalsilite bearing volcanic rocks - KAMAFUGITES, easily weatherable:
- **5-7 % $K_20$,**
- **10-15% CaO,**
- **12-16% MgO,**
- Low NaO,
- **$\sum$ CaO+MgO+$K_2$O+$Na_2$O = 31-34% (!)**
- **0.5-1.3% $P_2O_5$ (!)**
- $SiO_2$ 37-42 % (Si-undersaturated)

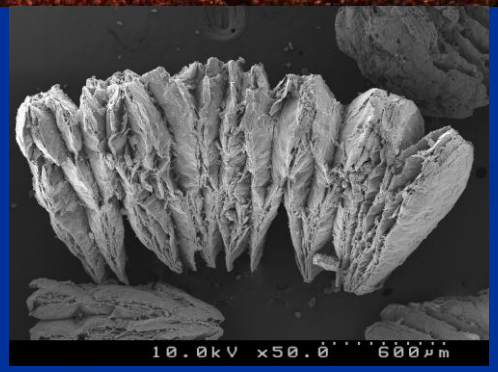
| Mineral | C 3948 | C 5775 | C 4793 | C 6066 | C 4035 | C 6099 | C 5595 | C 5783 |
|---|---|---|---|---|---|---|---|---|
| SiO2 | 36.64 | 32.29 | 37.1 | 40.15 | 41.06 | 41.84 | 39.84 | 40.75 |
| TiO2 | 3.96 | 4.94 | 5.62 | 3.32 | 3.94 | 4.1 | 5.1 | 5.31 |
| Al2O3 | 6.89 | 5.69 | 6.65 | 7.49 | 5.75 | 6.26 | 6.71 | 11.03 |
| Fe2O3t | 11.56 | 12.62 | 12.19 | 10.62 | 11.04 | 11.93 | 14.56 | 13.71 |
| MnO | 0.2 | 0.21 | 0.2 | 0.17 | 0.14 | 0.14 | 0.18 | 0.25 |
| MgO | 13.82 | 14.78 | 12.54 | 16.67 | 22.55 | 20.89 | 10.97 | 5 |
| CaO | 15.76 | 15.02 | 13.86 | 10.34 | 8.29 | 7.36 | 15.64 | 12.43 |
| Na 2O | 1.83 | 1.43 | 0.79 | 0.96 | 0.9 | 0.77 | 1.34 | 3.12 |
| K2O | 3.23 | 2.51 | 5.81 | 7.03 | 2.91 | 5.01 | 2.13 | 4.88 |
| P2O5 | 0.95 | 1.08 | 1.34 | 0.46 | 0.29 | 0.31 | 0.52 | 1.16 |
| LOI | 3.99 | 7.4 | 3.26 | 1.28 | 2.55 | 0.13 | 1.99 | 1.22 |
| TOTAL | 98.83 | 97.97 | 98.57 | 98.49 | 99.42 | 98.74 | 98.99 | 98.66 |

Source: Tappe *et al* 2003

# Planned use of quarry fines for banana/coffee production

# Ongoing vermiculite + Tithonia research






*Thithonia bilusifolia*

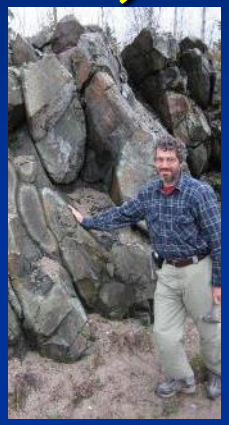
Organo-mineral product development - for sale

# Rocks for Crops research and development in Europe

## The players:

- Norway: Norwegian University of Life Sciences, Ås
- The Netherlands: Huig Bergsma
- UK: Prof. Manning and research group
- Sweden/UK
- France: Prof. P. Hinsinger and research group

# Agrogeological research at University of Life Sciences, Ås Norway (Heim *et al.*)



Prof. Michael Heim

- Focus on K-rich rocks and **tailings**
- Silicate rock as substitute agricultural liming material (150,000 t per annum)
- Silicate rock tailings as sources of micronutrients
- Co-Composting of Organic matter and tailings
- Ba phyto-toxicity and how to reduce it

# A technical breakthrough (?) Mechanical breakdown of K feldspar through high energy milling

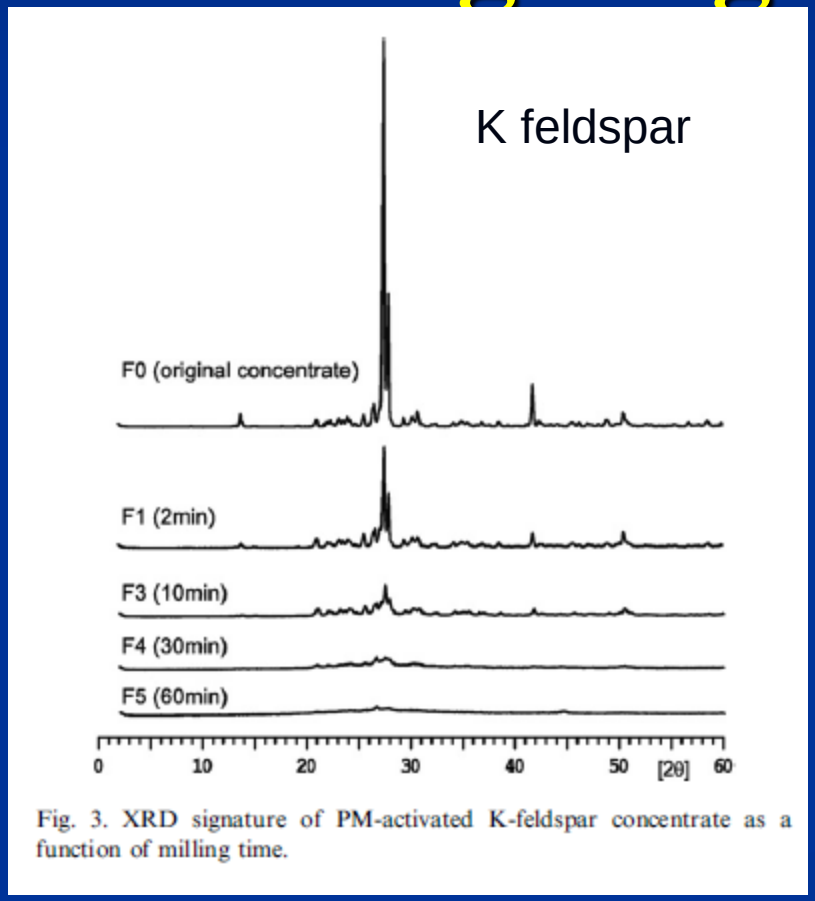
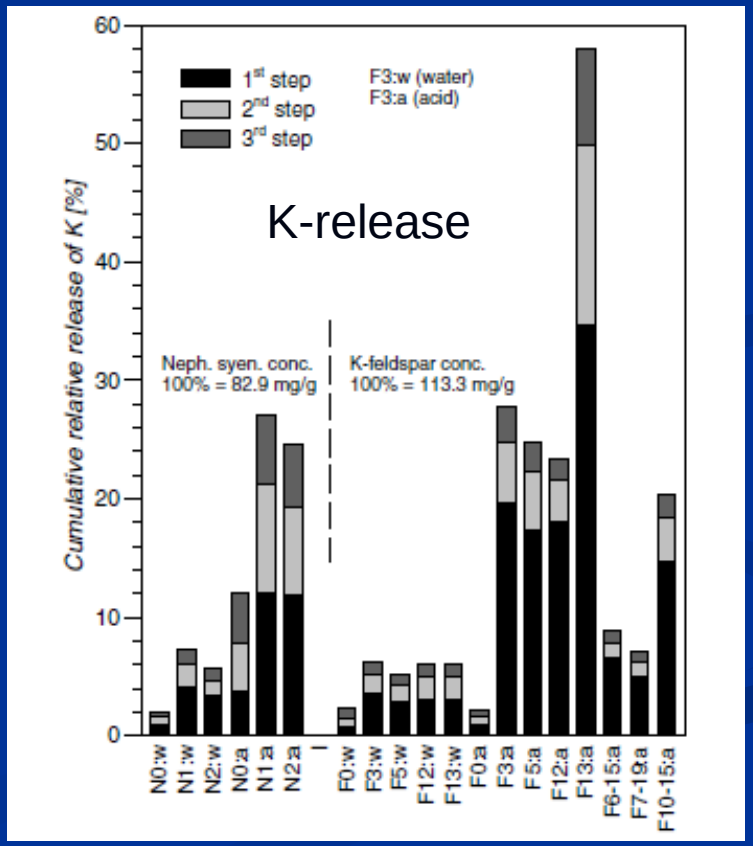



Fig. 3. XRD signature of PM-activated K-feldspar concentrate as a function of milling time.




Source: Kleiv and Thornhill 2007

# ‘Rock dust’ application in temperate climate (Sweden): why it could not work

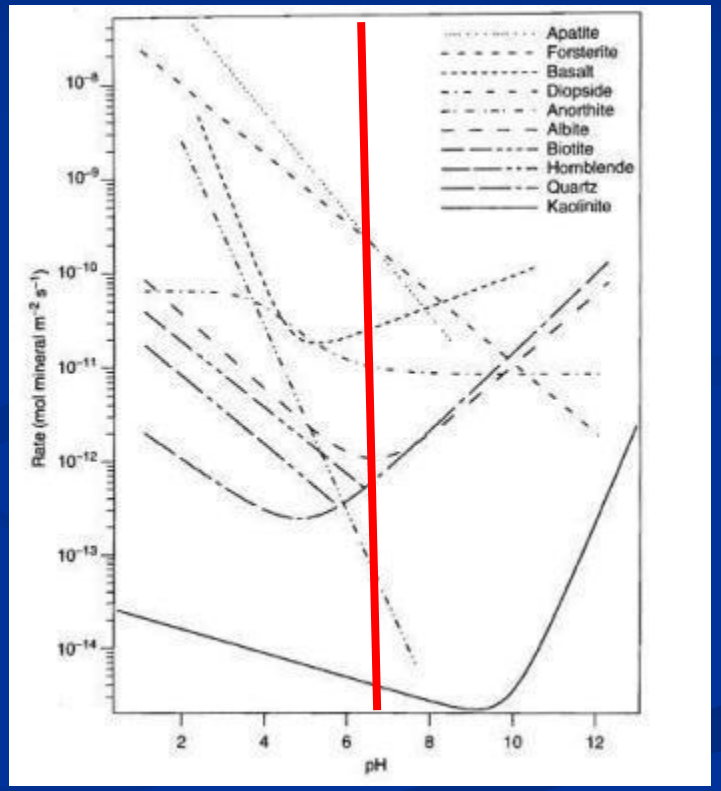
Plant Soil (2013) 367:419–436
DOI 10.1007/s11104-012-1474-2

REGULAR ARTICLE

## Addition of a volcanic rockdust to soils has no observable effects on plant yield and nutrient status or on soil microbial activity

Atefeh Ramezanian · A. Sigrun Dahlin ·
Colin D. Campbell · Stephen Hillier ·
Birgitta Mannerstedt-Fogelfors · Ingrid Öborn

Received: 20 July 2012 / Accepted: 20 September 2012 / Published online: 7 October 2012

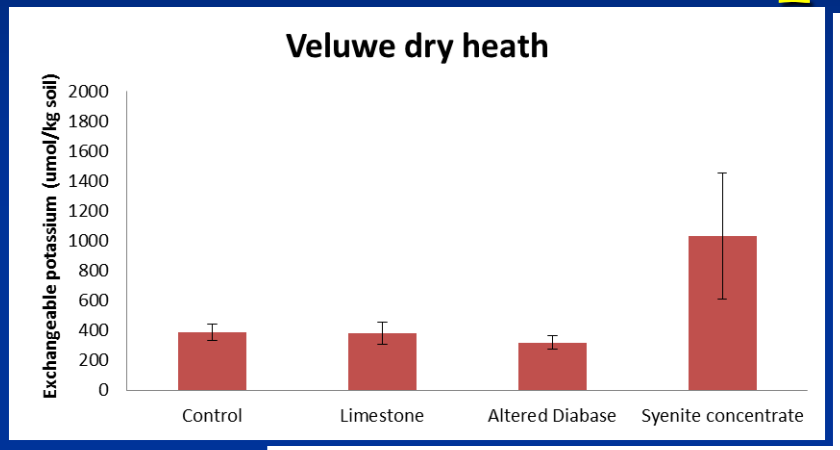

Source: Brantley 2008

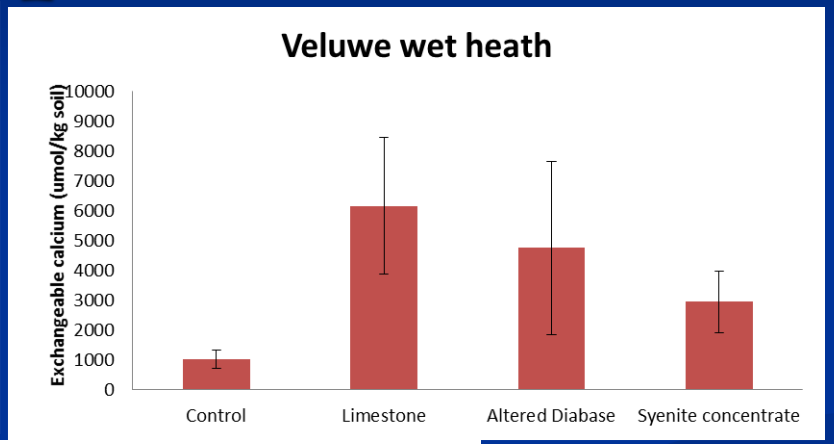
Rock powder (**pH 9.1;** Ca:5.36%, **Mg:12%, K:0.3% (low ratio K:Mg),** Fe: 20.20%), 15% clay
**Grain size too coarse: 30% 0.6-2mm, 30%> 2mm, Soil pH: 6.3-6.9;**
**Climate: temperate;** Test crop: Spring wheat, *Triticum aestivum* L.

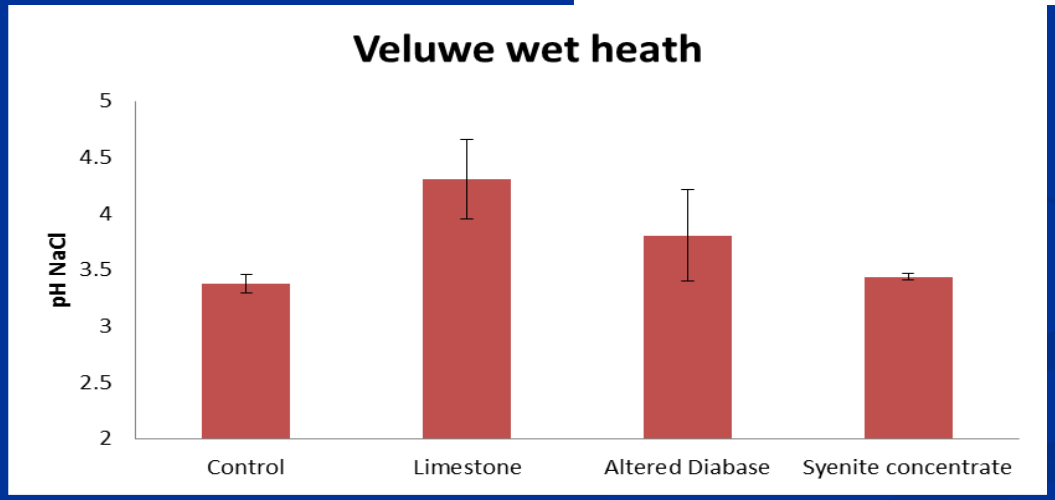
# Work by Huig Bergsma, the Netherlands, on use of 'Rock Dust' in Nature Reserves restoration projects

- Acid deposition has strongly acidified the soils in the Netherlands including nature reserves
- Many animal and plant species on the brink of extinction in these reserves.
- Repairing the damage with ground rock: application rate **10-20 tons/hectare**, grainsize < 1mm.
- Restoration work in several nature reserves in the Netherlands ongoing and planned

# Monitoring plant available $K^+$ and $Ca^{2+}$ and pH soil 6 months after application

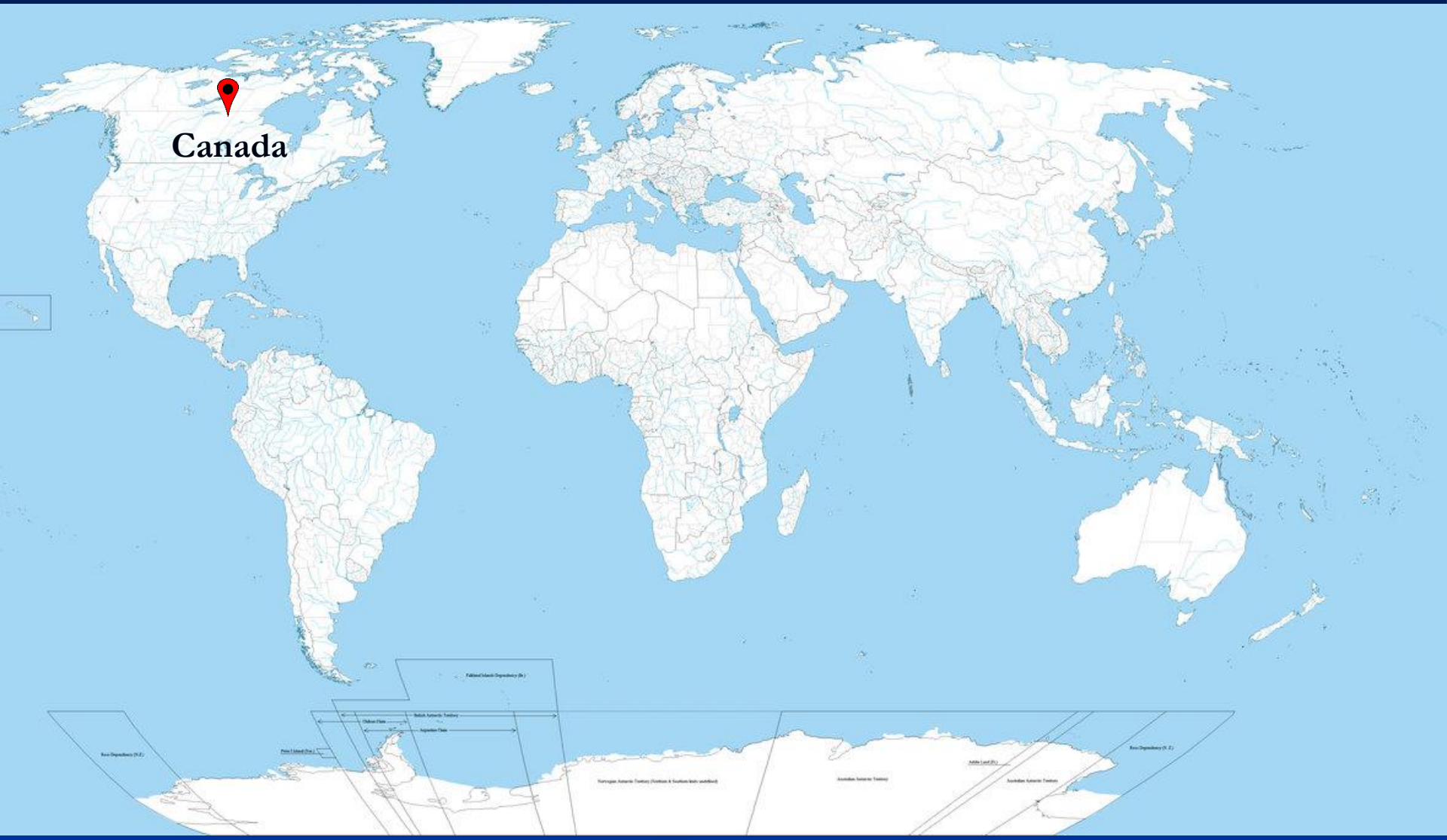


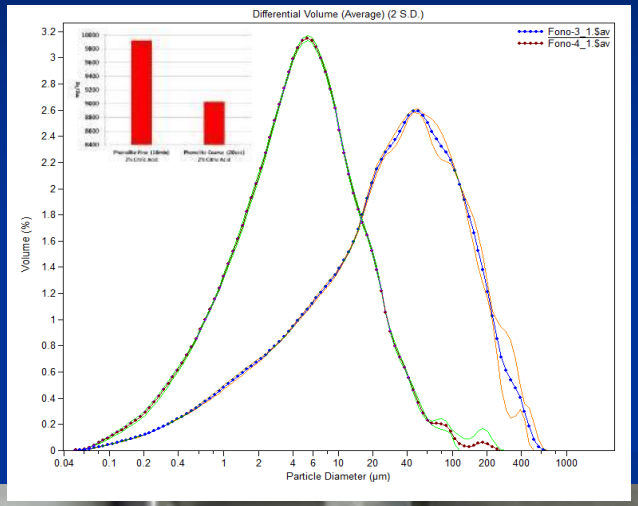




Maaike Weijters et al. 2016, B-ware ecological research.

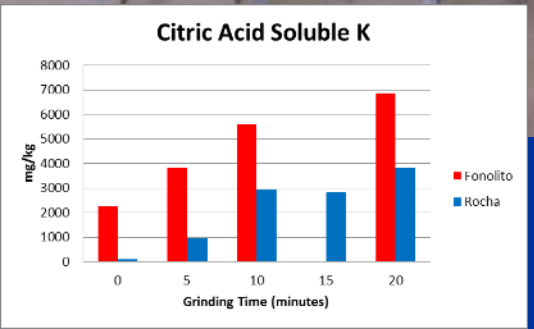
# Appropriate technology development in Canada



# K-rock modification: Enhanced K release through micronizing with novel 'appropriate technology' grinding equipment



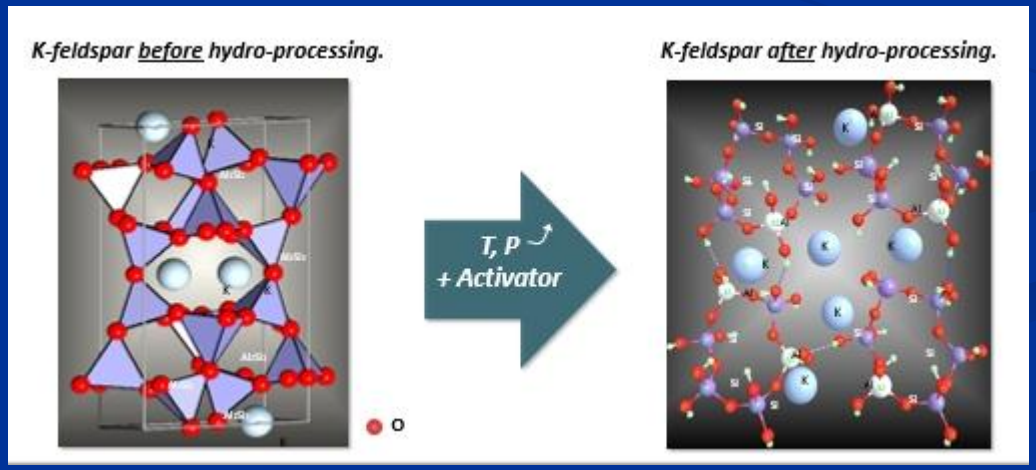

K release due to fine grinding of phonolite




Appropriate Technology Grinding Equipment from Rock Powder Solutions, Ontario, Canada

# New development: proto-type pin mixer

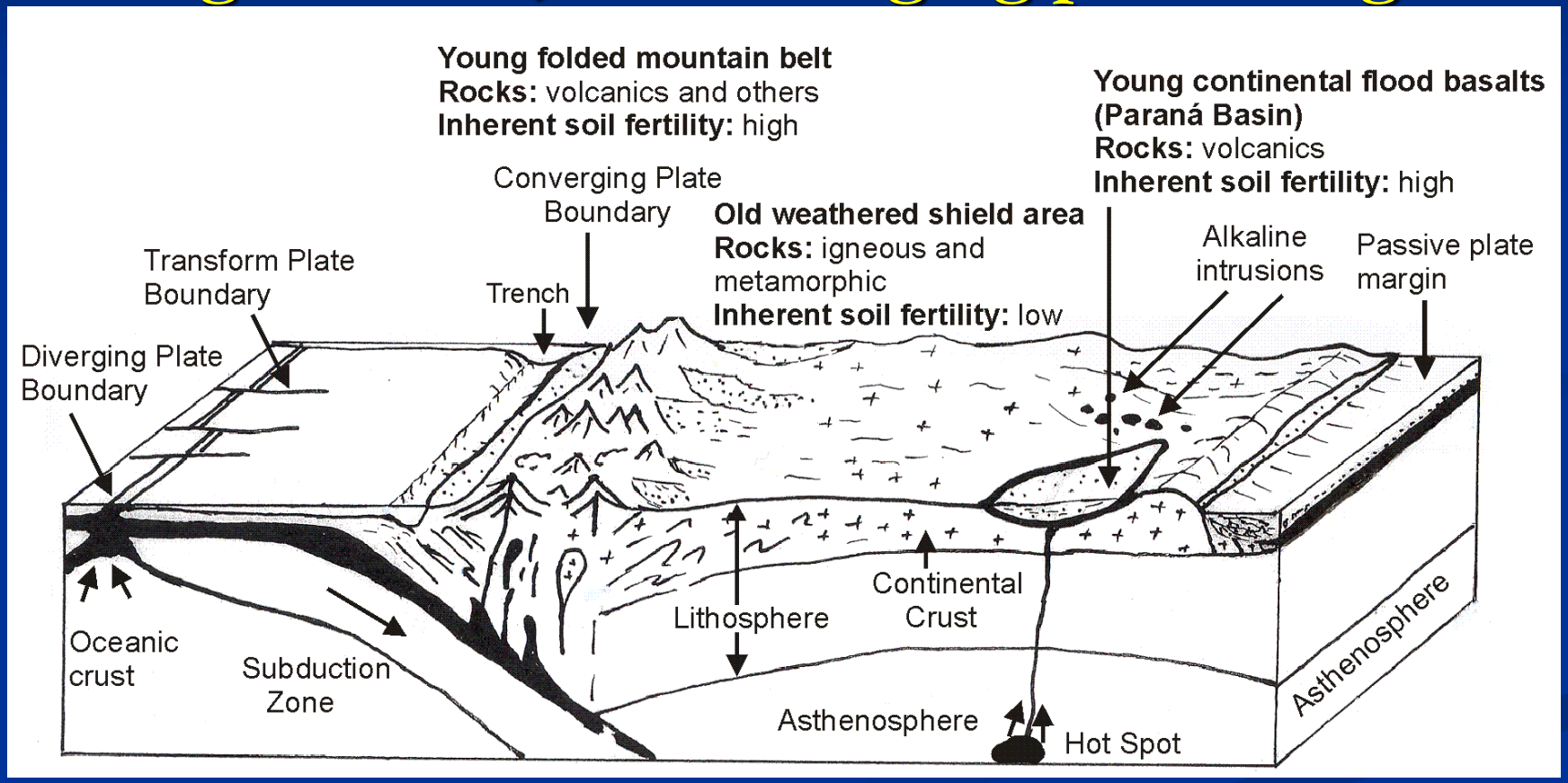
# K-feldspar research and development (Terrativa/ MIT)



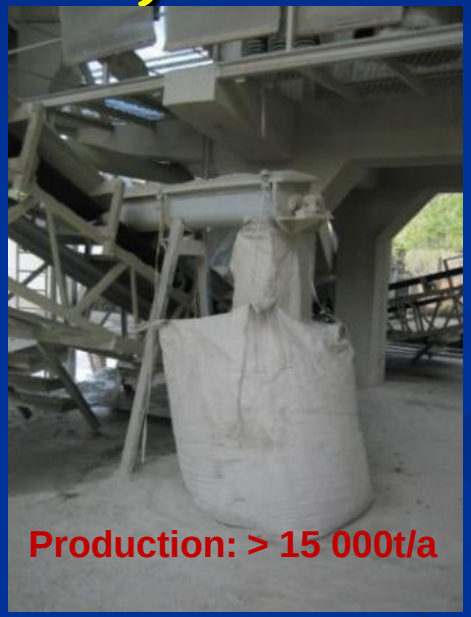

Enhanced K release from K-feldspar
Source:
Ciceri and Allanoure

# Brazil, the ‘epicenter’ of rocks for crops’ research and development

# Geotectonic setting and agromineral potential of Brazil: Rift with carbonatites; kamafugites; alkaline intrusions; flood basalts, passive margin basins, no converging plate margins



# Existing, commercial silicate-rock fertilizer production from Poços de Caldas, Brazil




For:

# Brazil: the epicenter of 'Rocks for Crops' research and development


# Rocks for Crops research and development in Brazil

- Company that actually produces and sells agrominerals commercially in Brazil
- Progress in exploration and testing of different rock types and wastes
- Progress in research and development of direct application of multi-mineralic rocks (Rochagem)
- Progress in innovative separation processes, e.g. physical separation of different mineral fractions
- Progress in innovative microbial dissolution work

# Summary: Rocks for crops research and development in the world

- Often driven by geoscientists or soil scientists, often little interaction with other stakeholders, rarely with farmers
- Exploration for and evaluation of different rock types suitable for different soils and crops
- Main work on voluminous 'direct application': results are patchy and inconsistent **due to complexity of system**
- Few places with innovative processing techniques, e.g. microbial dissolution, micronizing, pelletizing, nutrient extraction through 'liquid rock extract'
- Only little R&D work on 'rocks for trees'

# Research and development (R&D) needs:

- Better tailoring: Which rocks are best suited for which soils, for which crops?
- Innovative biological/chemical modification of rocks and minerals: e.g. using LMW organic acids, enhancing nutrient release through microorganisms e.g. on mineral 'wastes'
- Innovative physical modification: mineral separation from different rock materials including 'wastes', high energy milling, (hydro)-thermal treatment of different rock types
- Emphasis on organo-mineral research, e.g. using different rocks in composting operations, 'rock composting'
- More R&D on 'Rocks for trees', including fruit trees

Thank you

Obrigado

pvanstra@uoguelph.ca