The contribution of micromorphology to science

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What is soil micromorphology? (micropedology)

- Micromorphology is the observation and interpretation of
- undisturbed , oriented samples
- with microscopic and ultramicroscopic techniques
- in order to identify their constituents (including voids) and
- to determine their mutual spatial relations in space and time, including the anisotropy.
- allowing to deduce genetic and chronological relationships

- garnet, glass, gold, iron, cupper, gold…
- % Si, Al, Fe, Au, Cu,…..
- → understanding

Difference with other soil disciplines

- Soil chemistry, mineralogy, plant nutrition, physics, etc. deal with homogenised bulk samples; heterogeneity and anistropy are lost. E.g. total content of calcium carbonate

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- Micromorphology allows to observe and measure in undisturbed samples the microheterogeneity and anistropy . E.g. calcite: lithogenic or pedogenic ,as coatings or nodules, decalcification around roots.
- Voids are considered as components

Scale and methods

- Macromorphology: hand lens, natural samples (cm – mm)
- Mesomorphology: stereomicroscope, natural samples (mm)
- Micromorphology: petrographic microscope, thin sections (mm - µm)
- Submicroscopy: electronic microscopes, thin sections or fractures (µm)

Study of thin sections

- Petrographic microscope (plane polarised light, crossed polarisers, circular polarised light, oblique incident light, blue light- and UV light fluorescence, cathodoluminescence, etc.)

  Staining and dissolution tests
- Analytical tools: Microprobe, micro-XRD, micro-XRF, micro-FTIR, LAMMA, etc.

History

- **Kubiëna 1938**:

  « *Micropedology* »

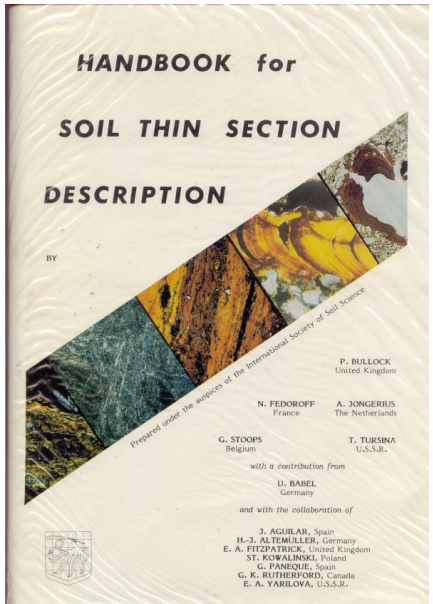
  first handbook

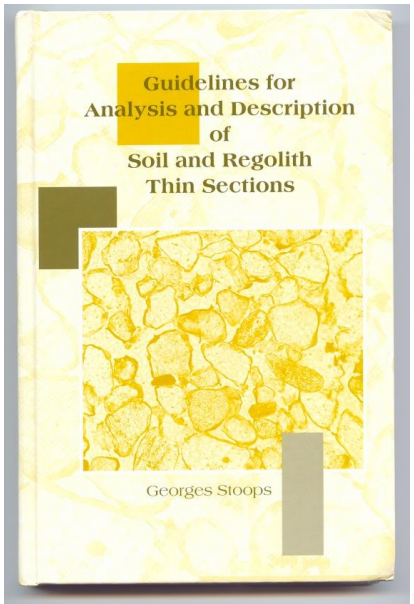
  morphoanalytical
- **Kubiëna 1948**

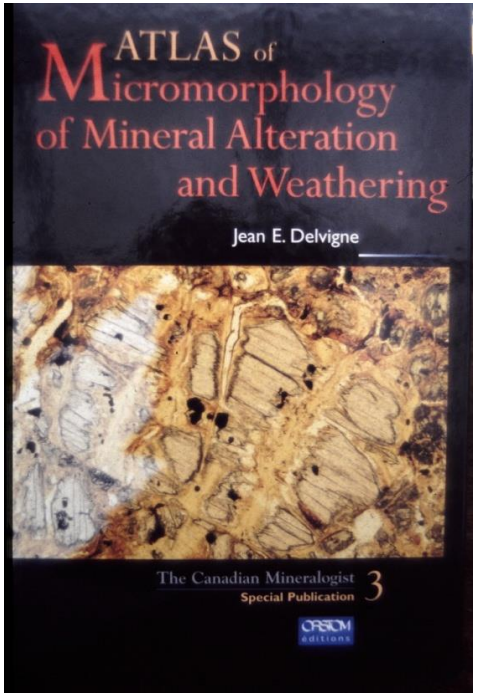
  morphogenetic (linked to soil classification) e.g. Braunerde, Rotlehm

Later developments
Morphoanalytical systems

- Brewer 1964
- Bullock et al. 1985 (ISSS-supported system)
- Stoops 2003: based on Bullock et al. 1985
- Delvigne 1998 (weathering)

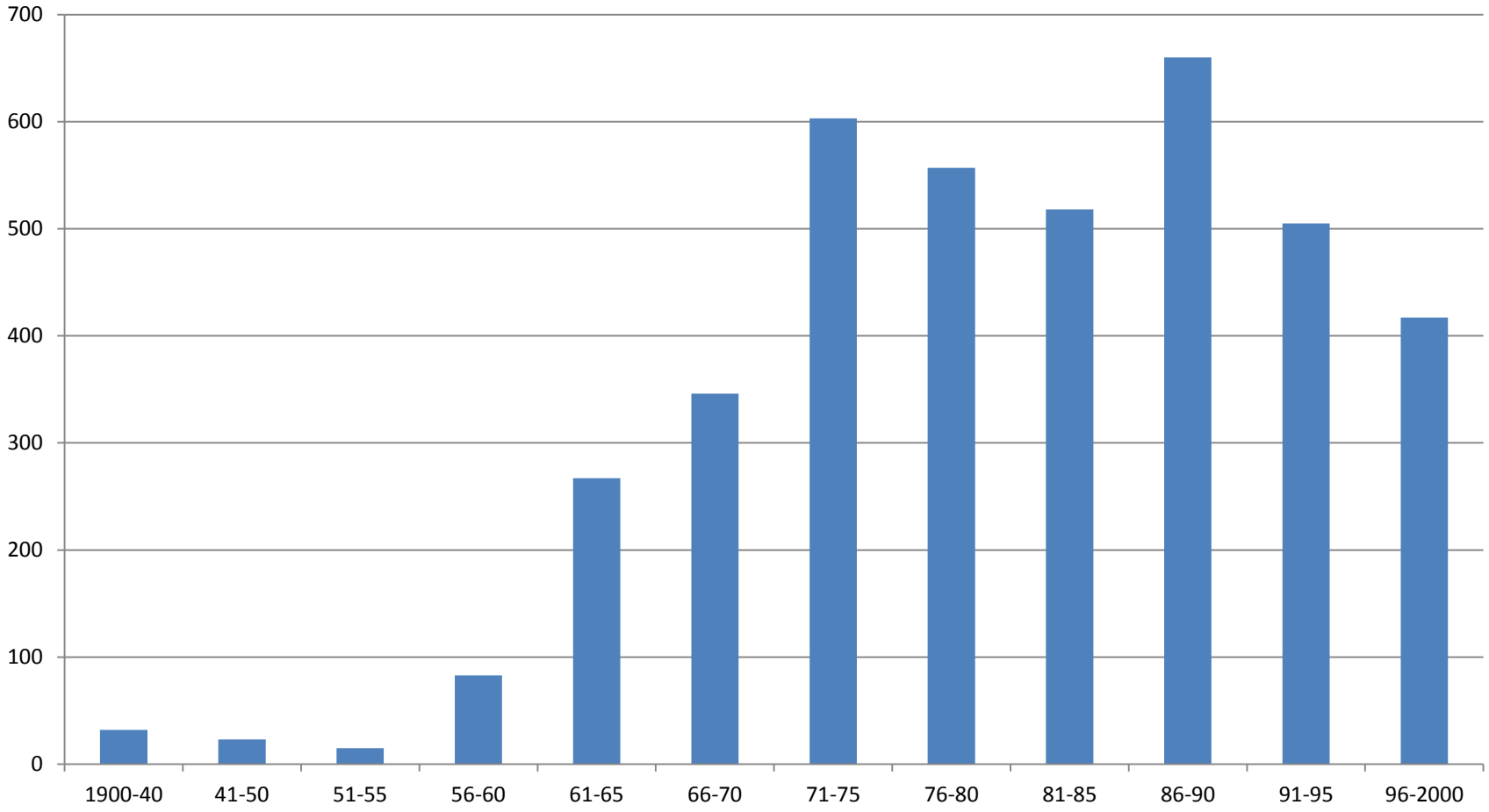




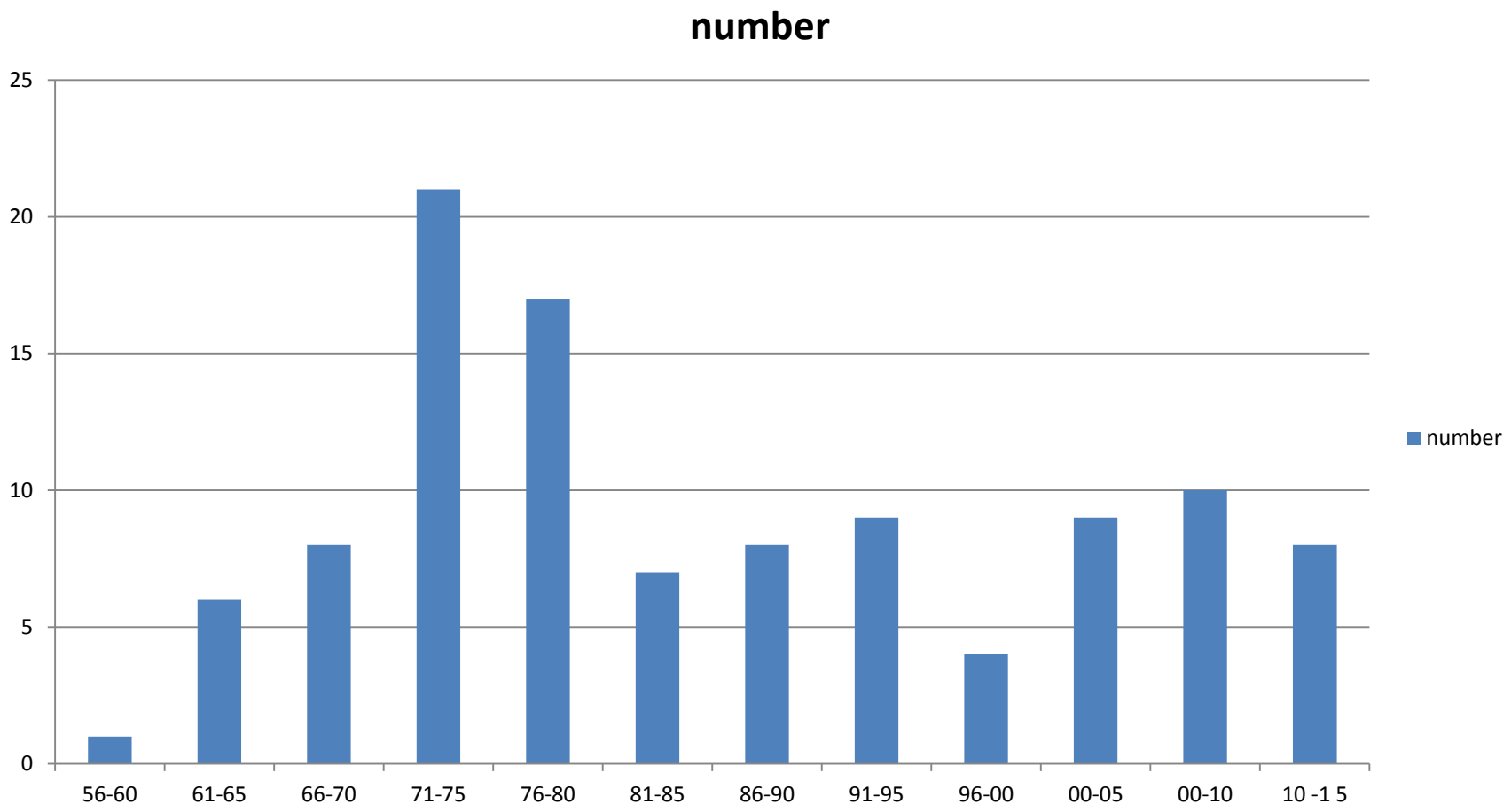


Evolution of publications worldwide

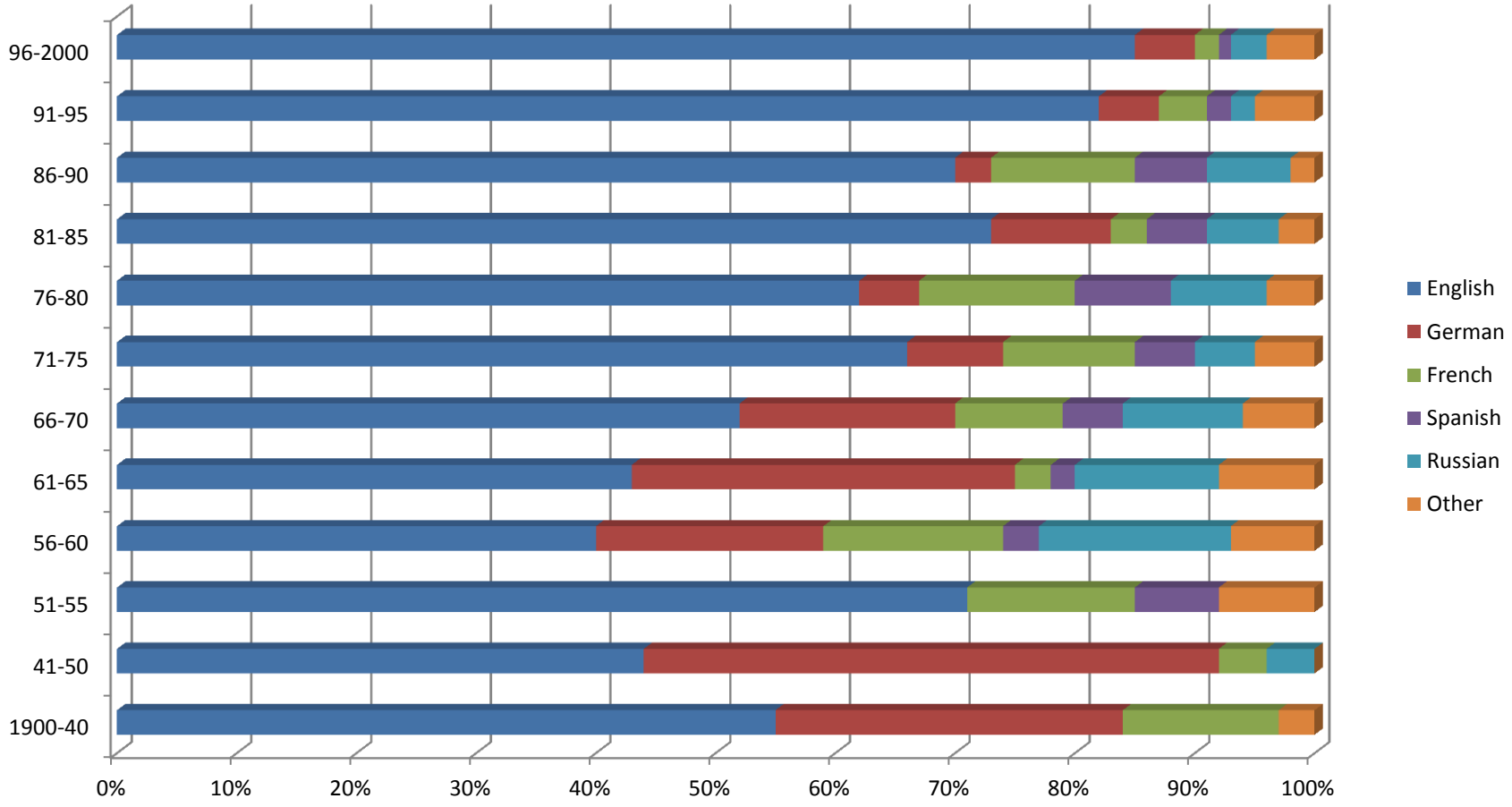
Total number of publications



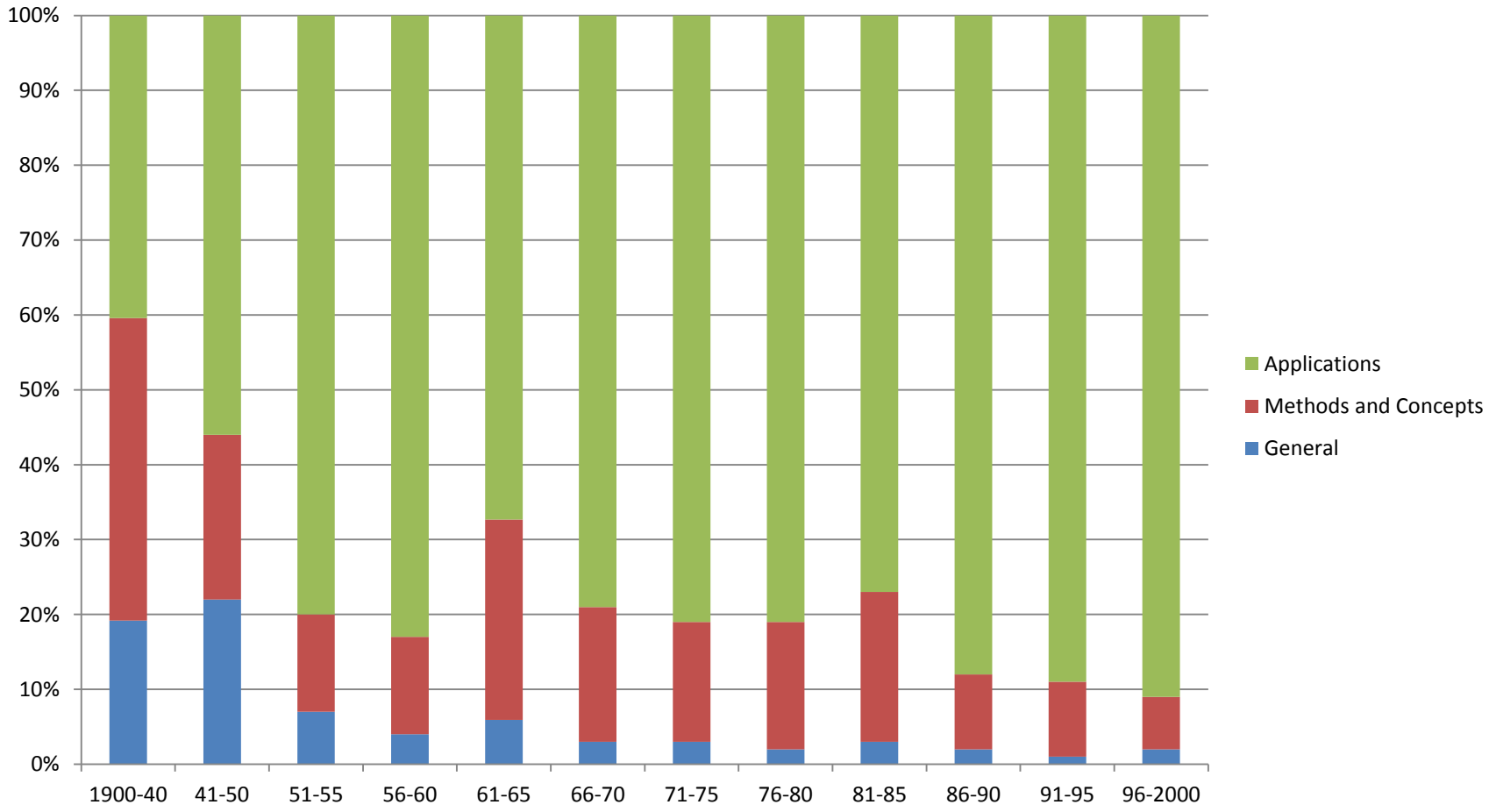
Polish publications



Languages used



Topics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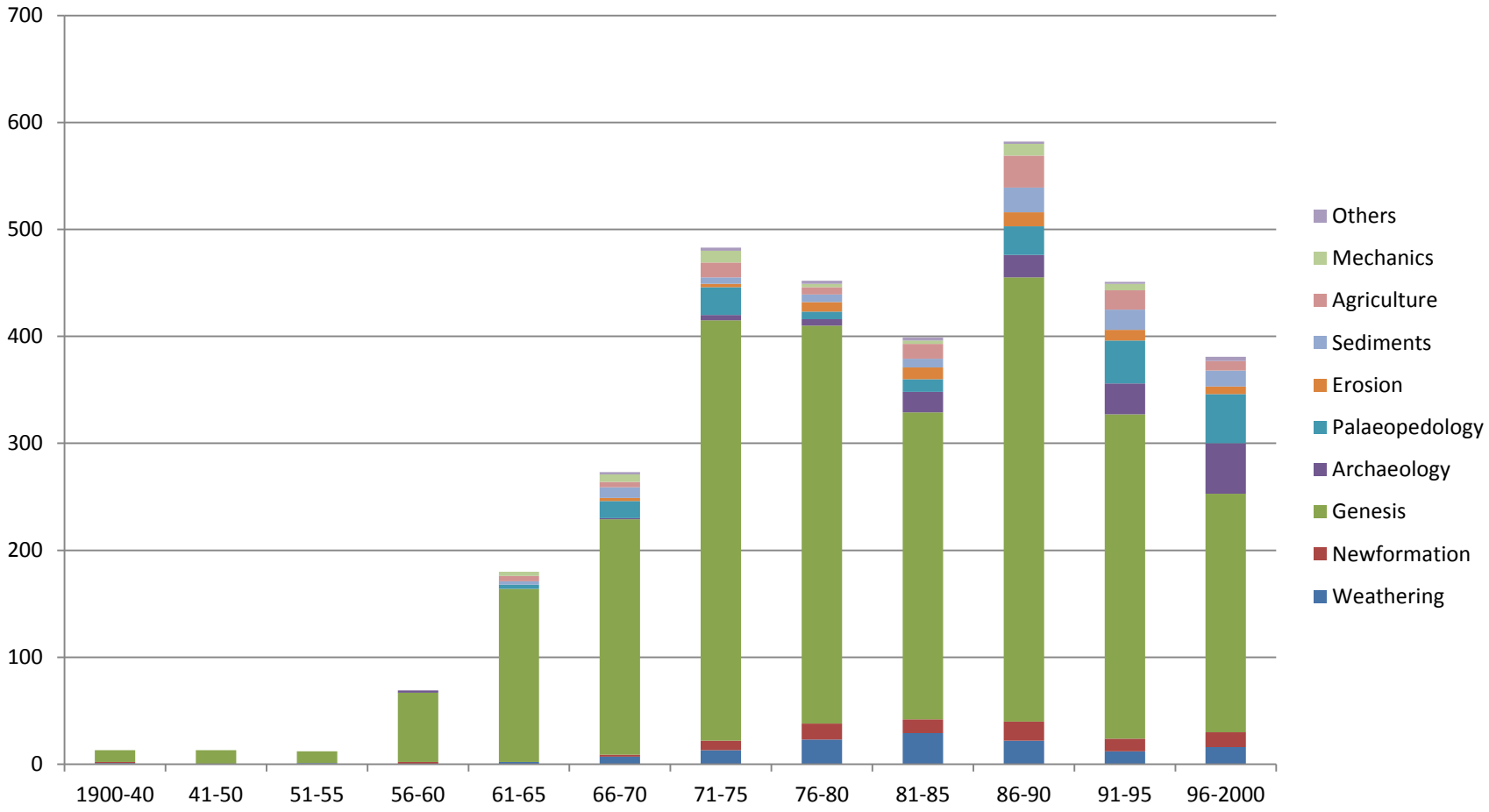
96-2000
Applications
Methods and Concepts
General

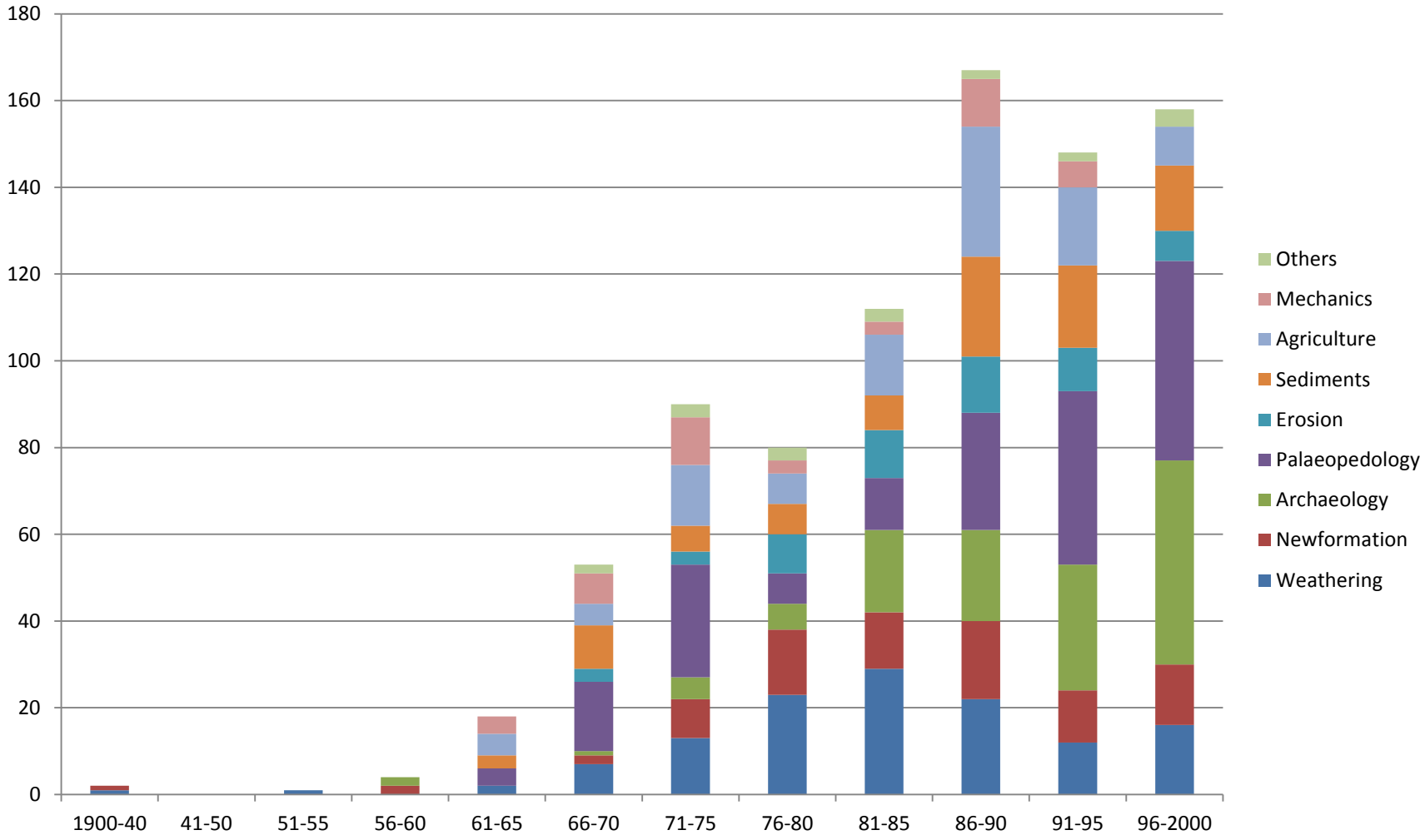
Application in different fields

- Soil science
  - Genesis
  - Classification
  - Mineralogy (including weathering and neoformations)
  - Agriculture (soil physics, soil chemistry)
- Palaeopedology
- Quaternary geology
  - Landscape formation (sediments, erosion)
  - Sediments (especially glacial)
- Archaeology
  - Fabric
  - Materials
- Material studies

Evolution of application fields



Applications others than genesis and classification

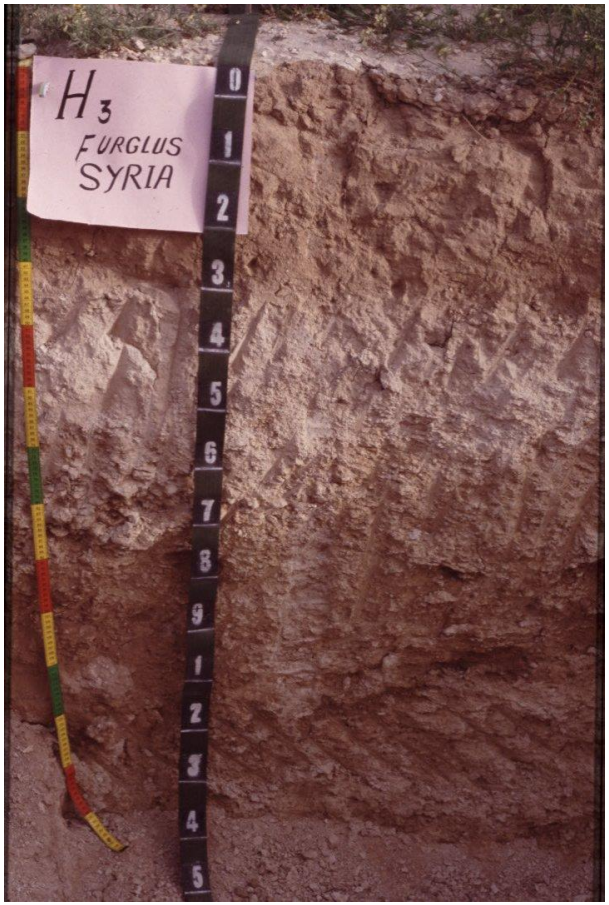


Micromorphology and soil genesis Examples

- The gypsic horizon is not only a precipitation
- Laterites are complex, heterogeneous bodies

- Almost all soils are polygenetic (e.g. different types of clay coatings in Luvisols)
- Processes show rhythmicity
- Pedogenesis is not a continuous process in one direction

Formation of gypsic horizon



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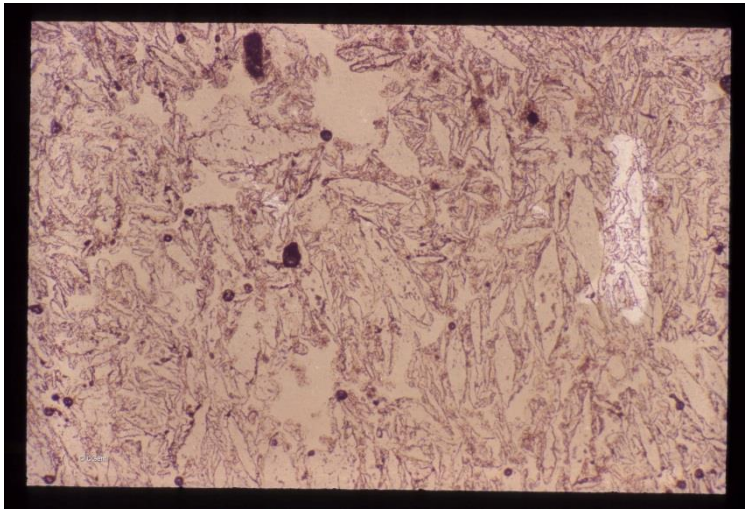
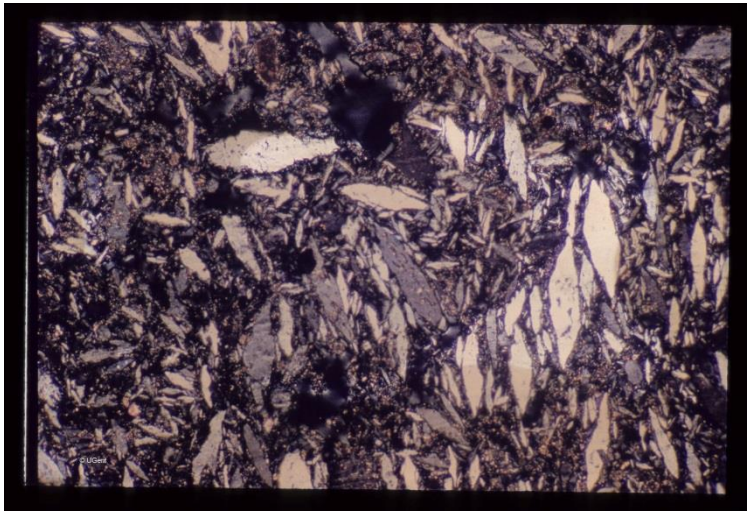
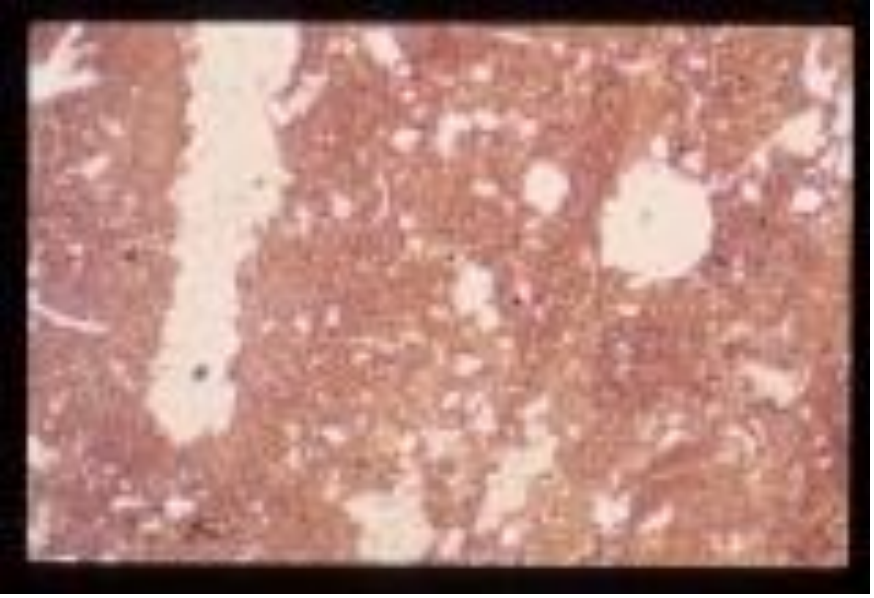
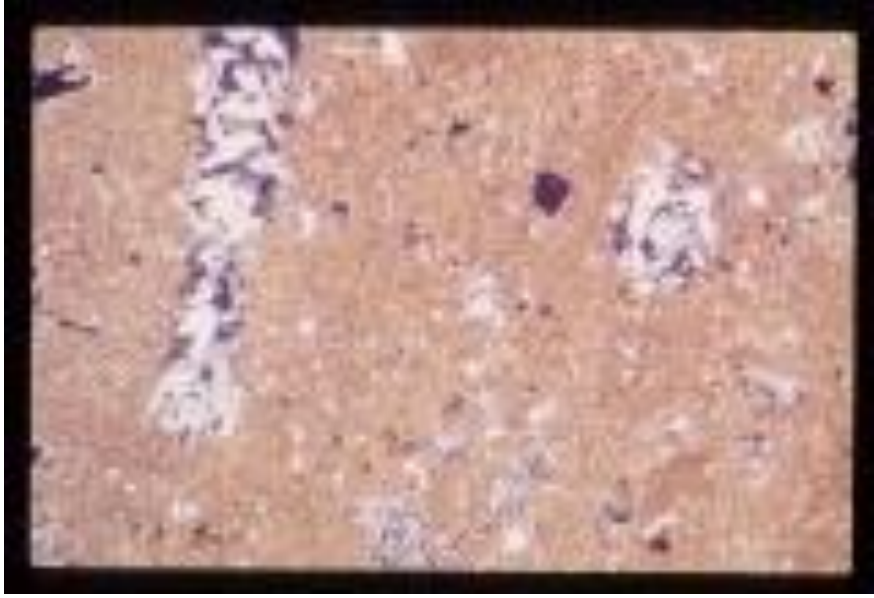
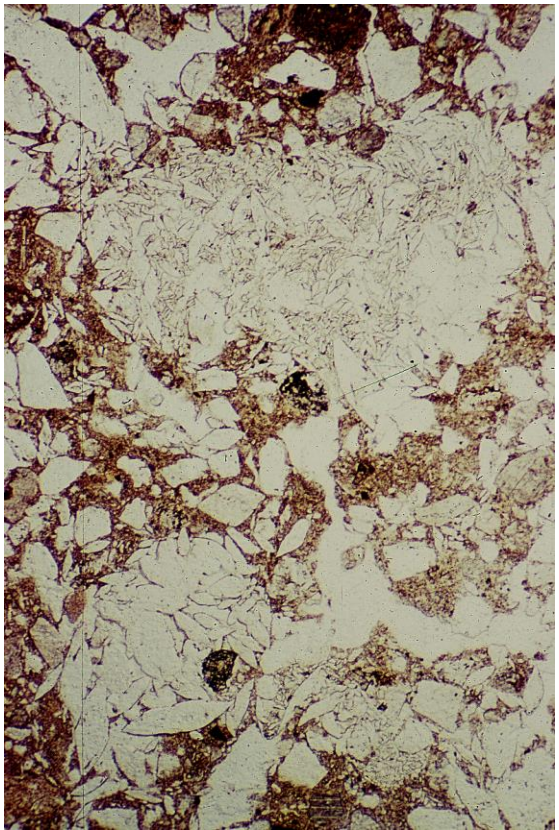
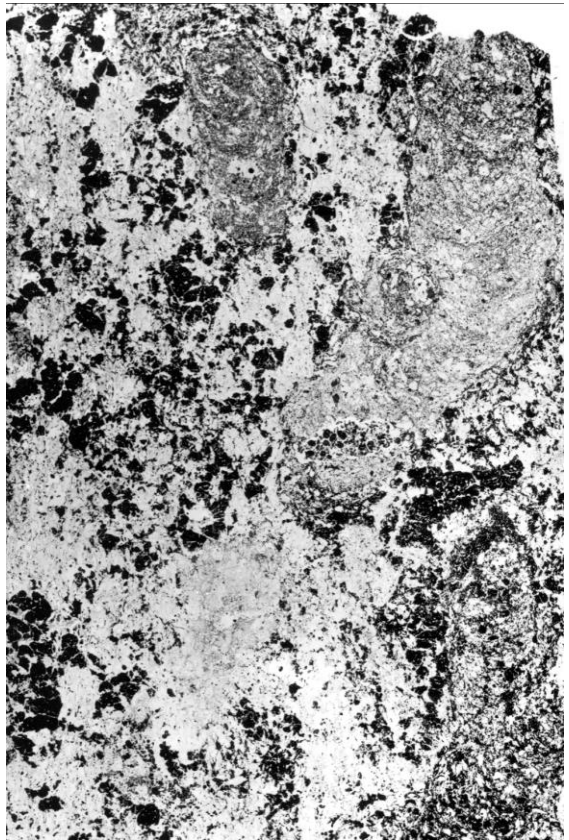


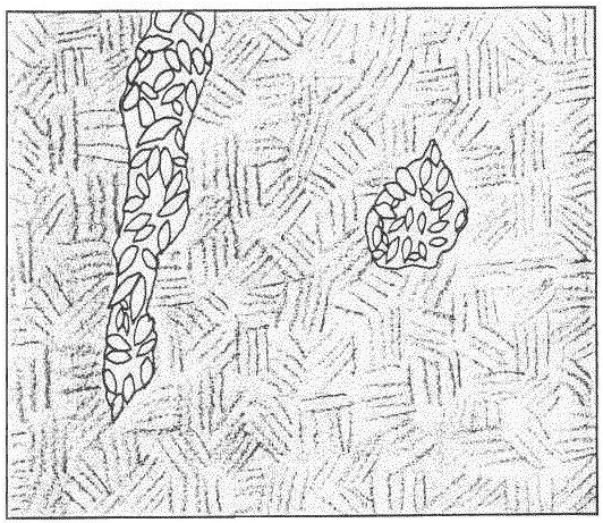


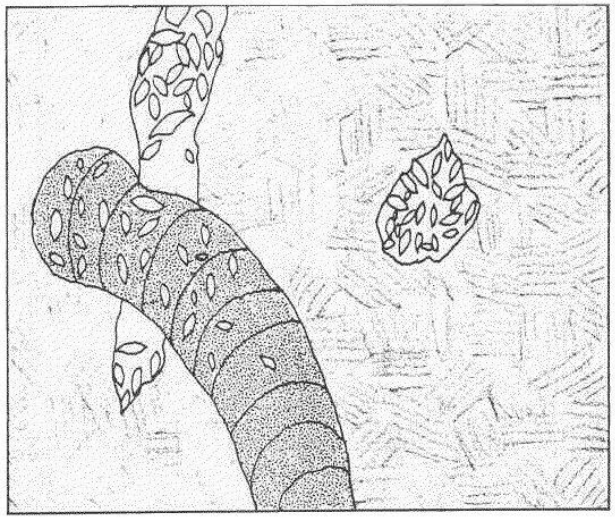


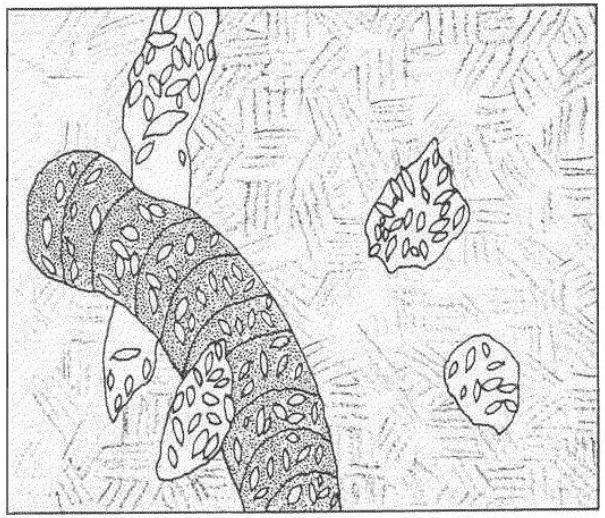


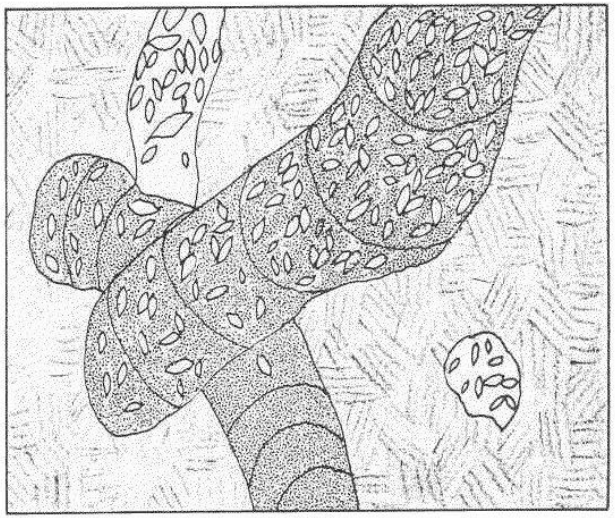


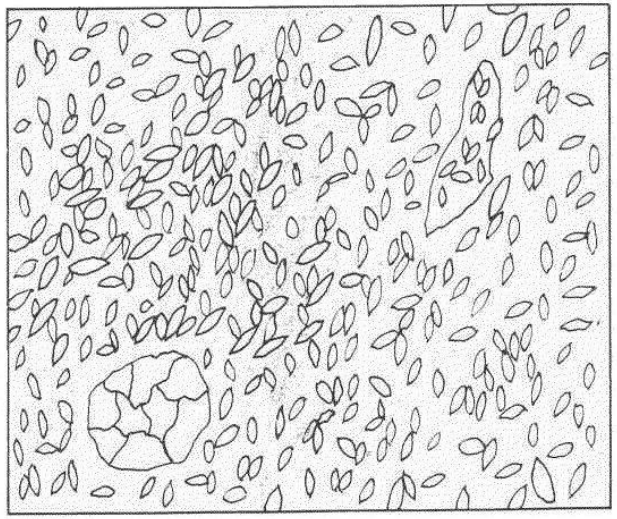


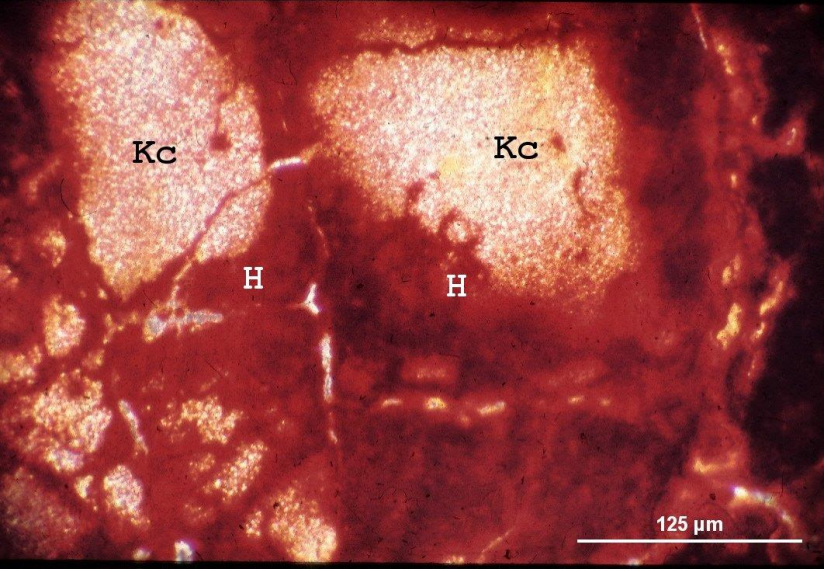


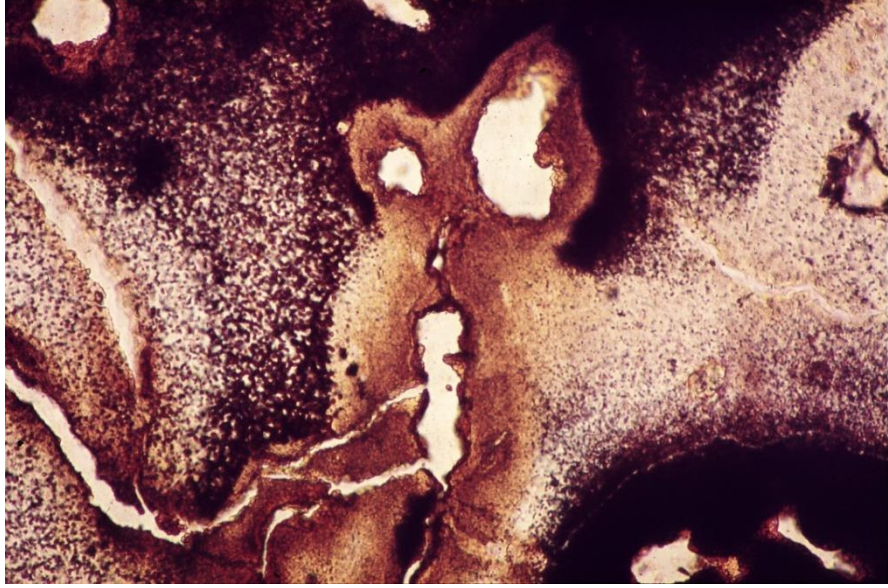




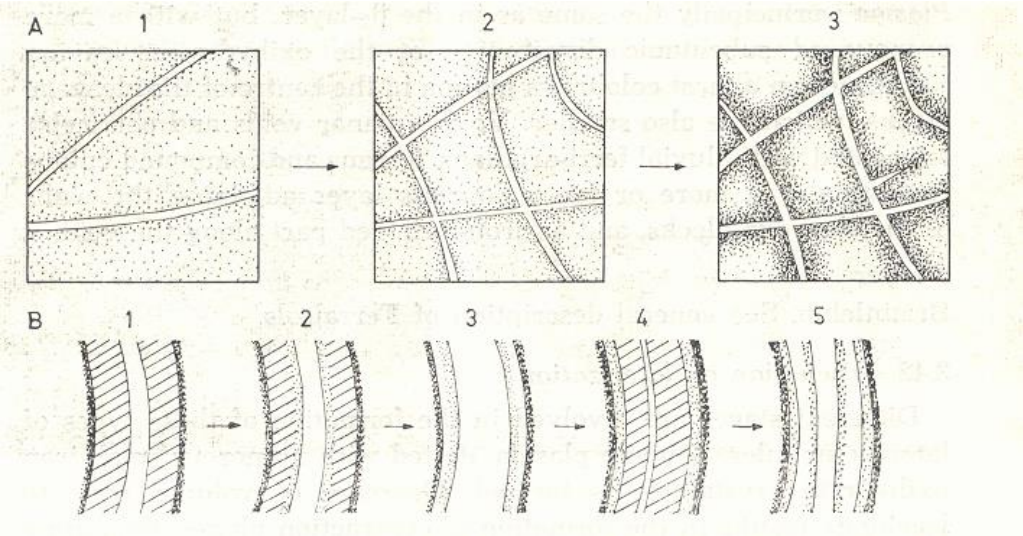


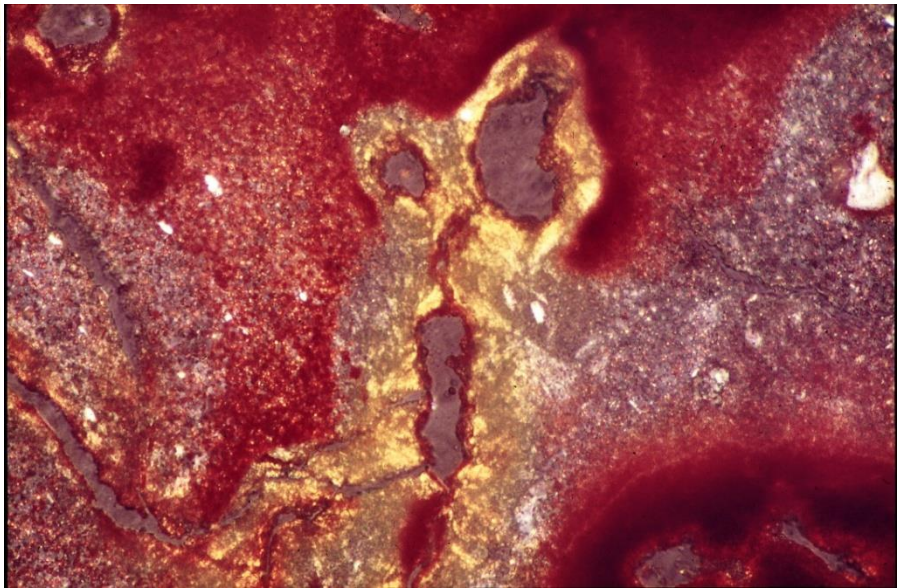




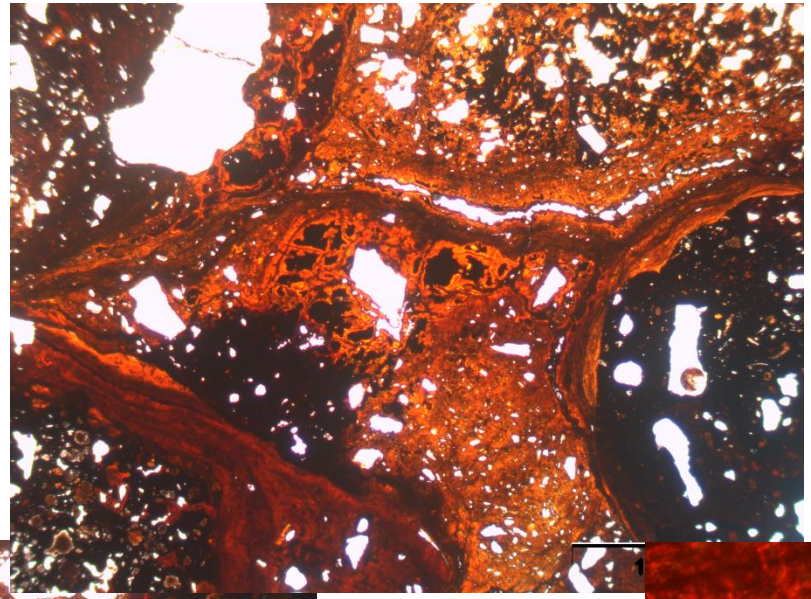


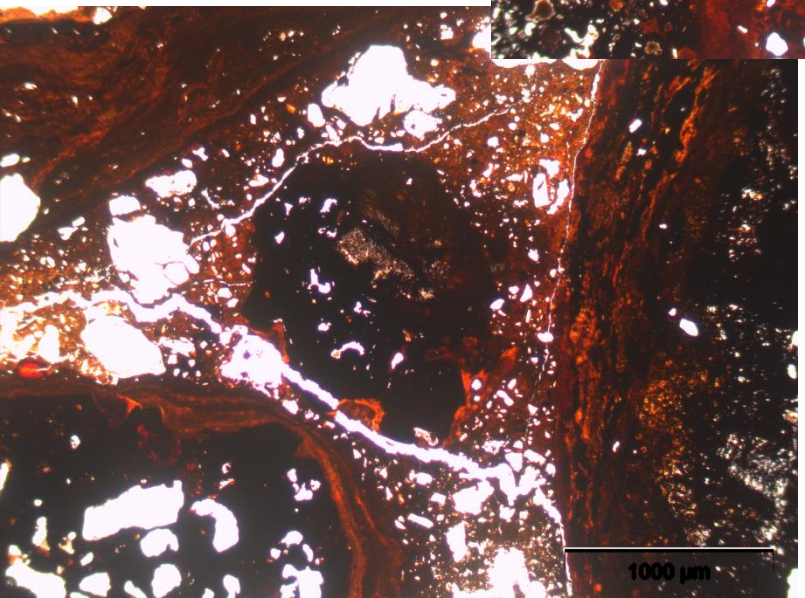
- Laterite genesis is complex

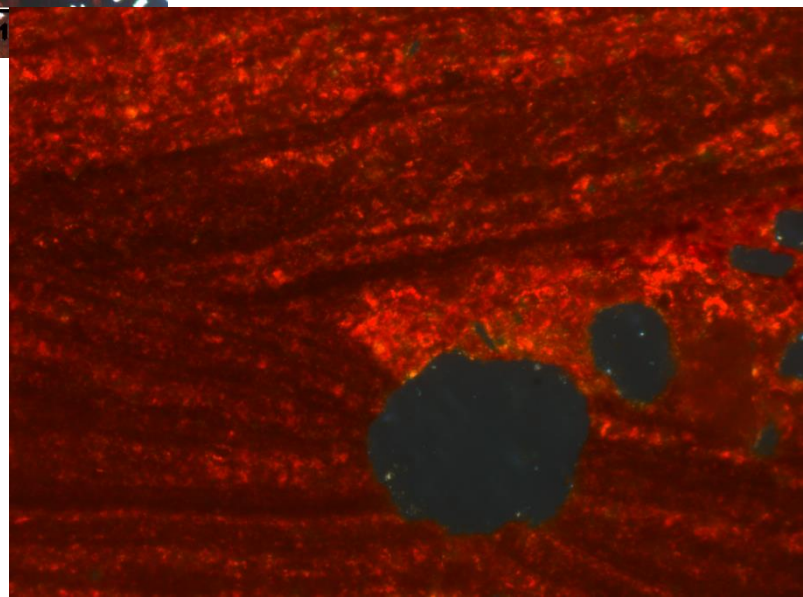


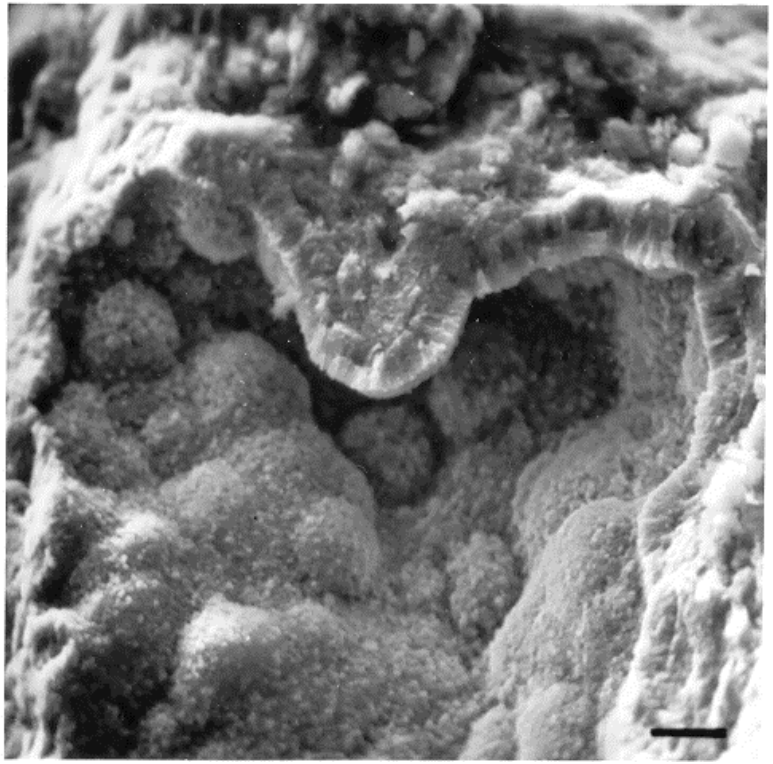


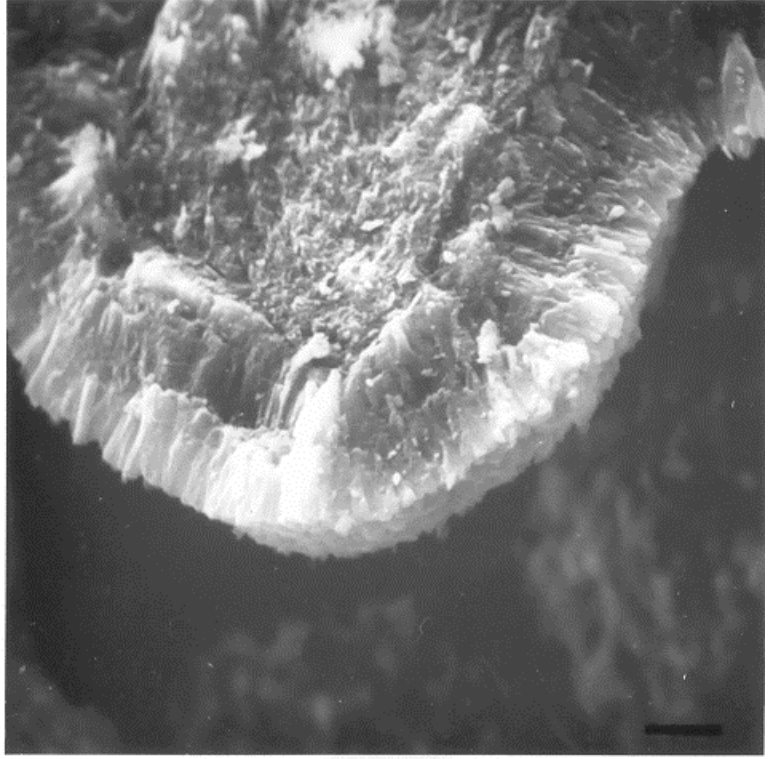
Complex laterite genesis

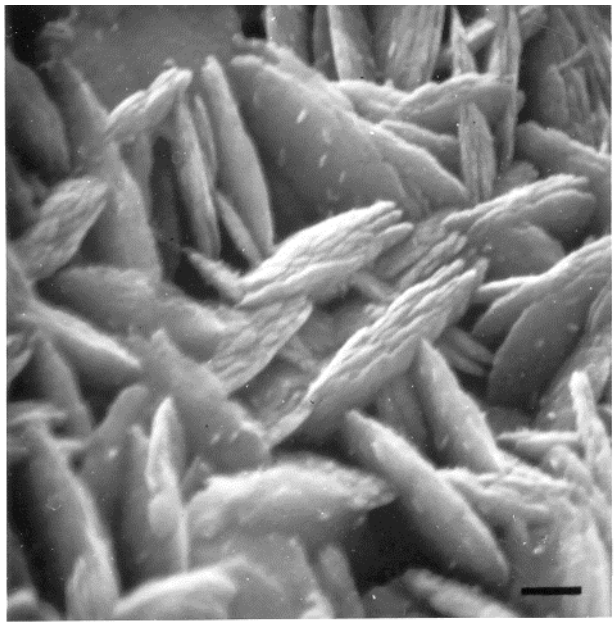


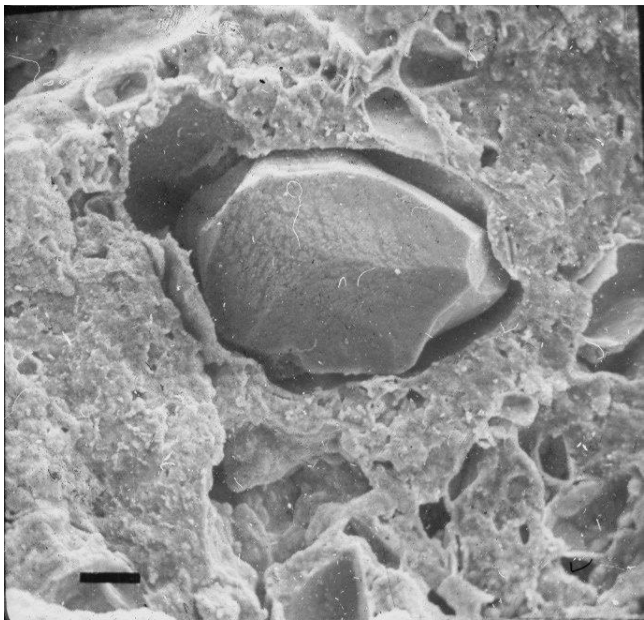




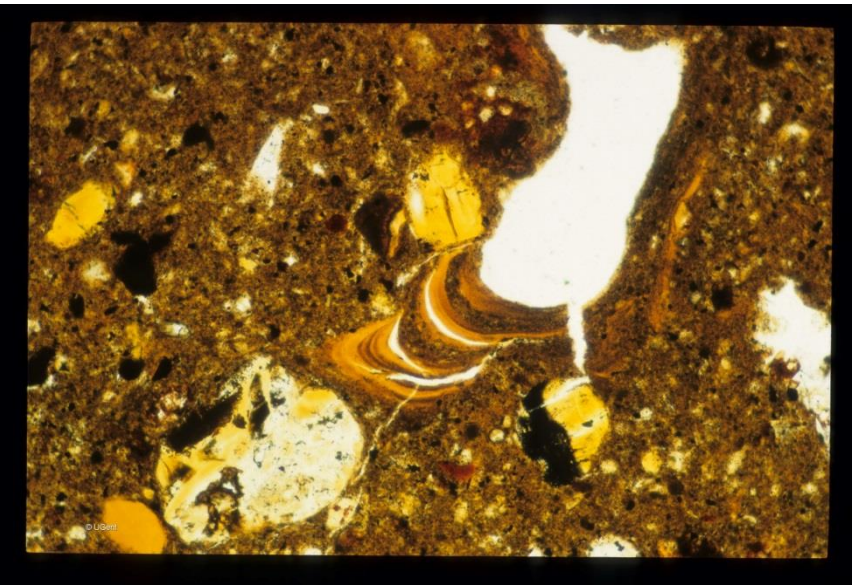


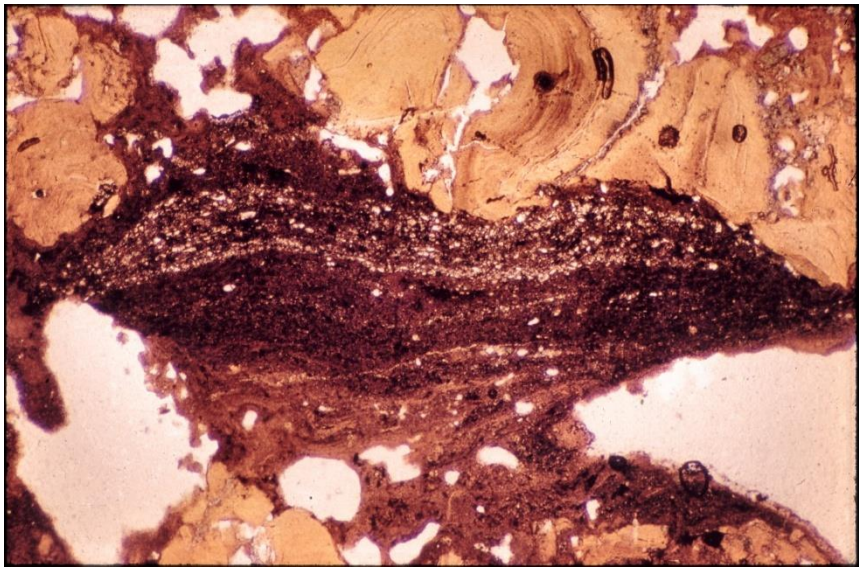


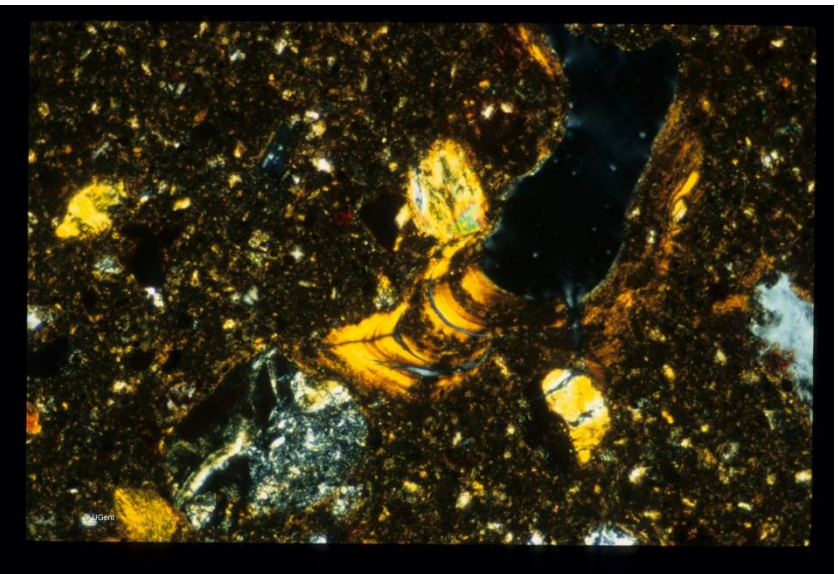


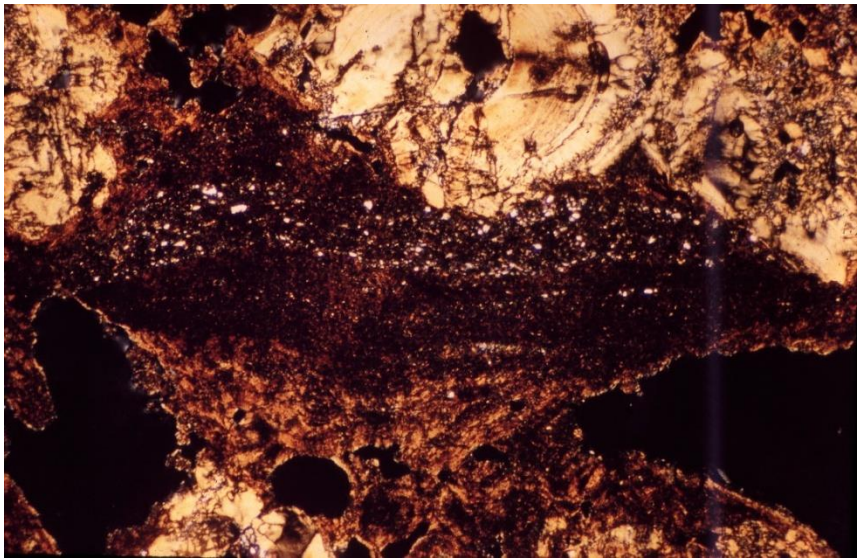


Chronology of events and anisotropy

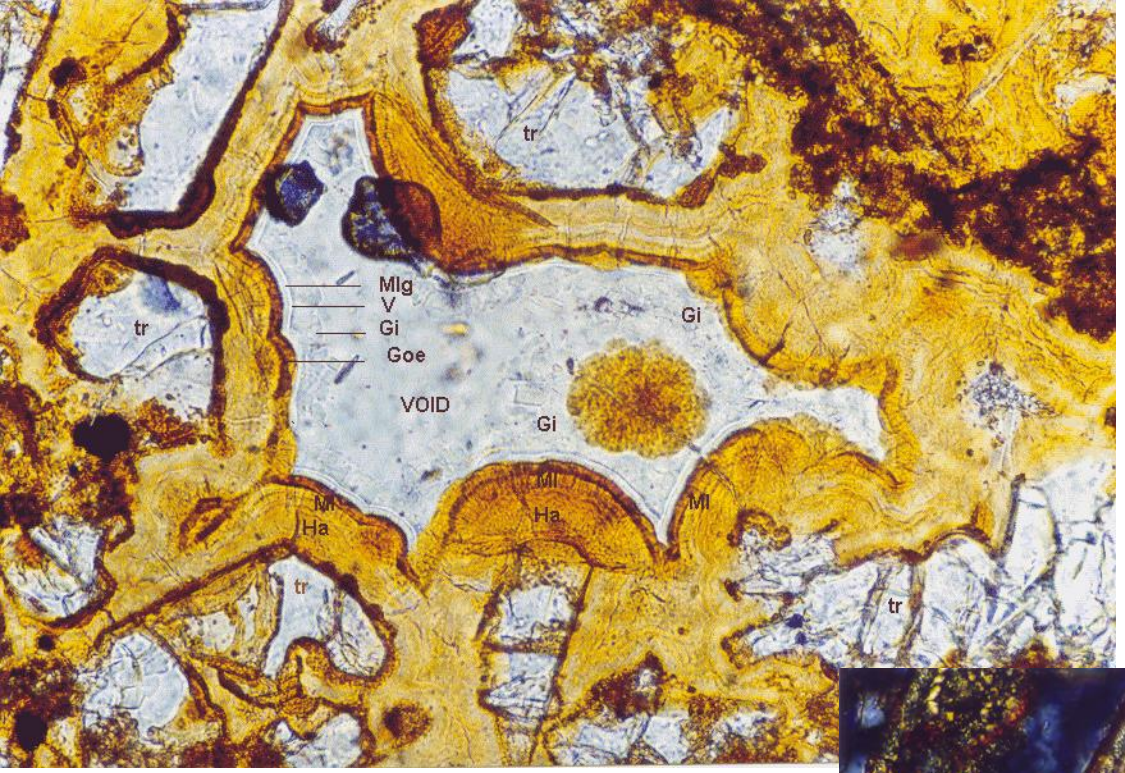


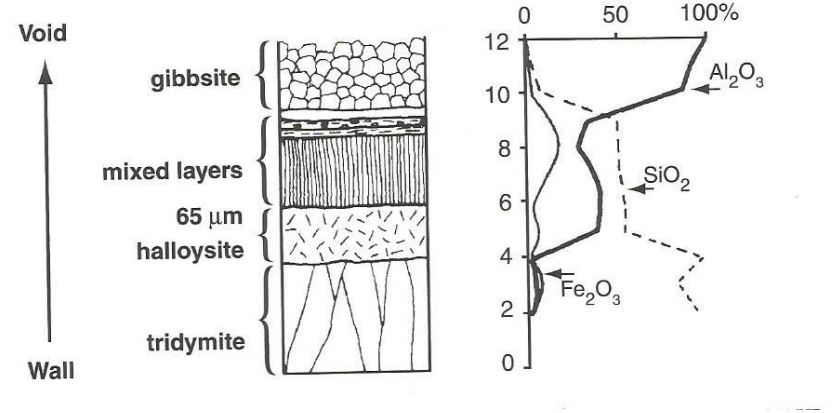


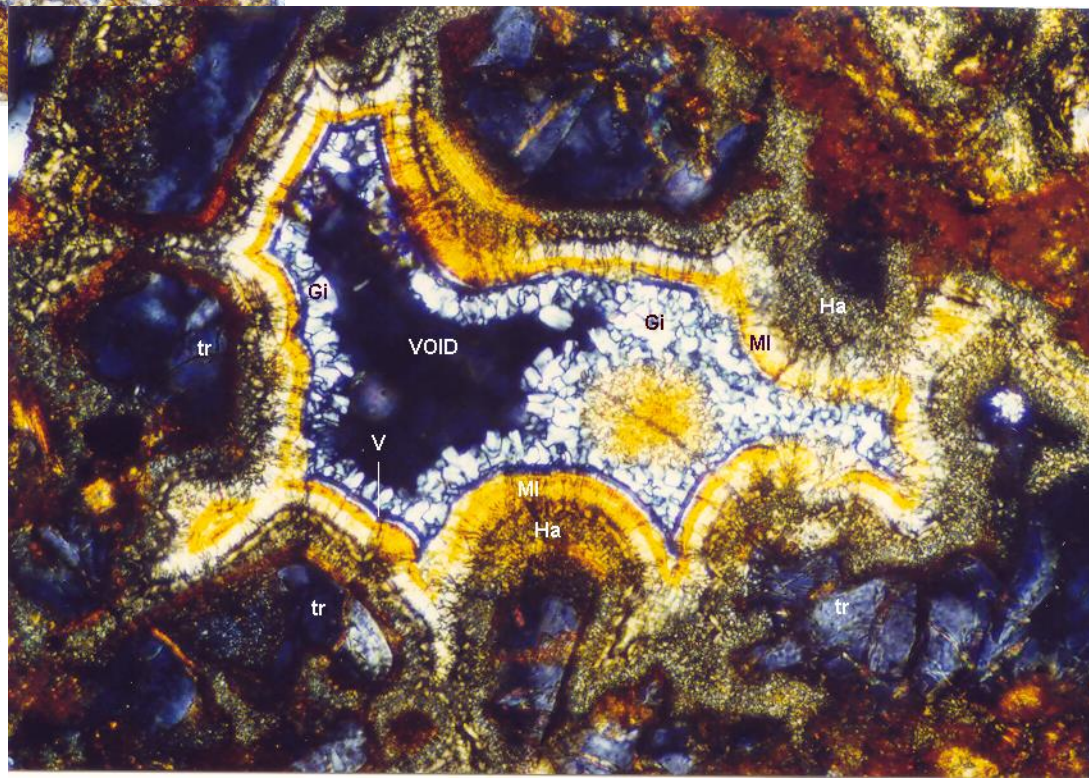




Weathering of andesite boulder







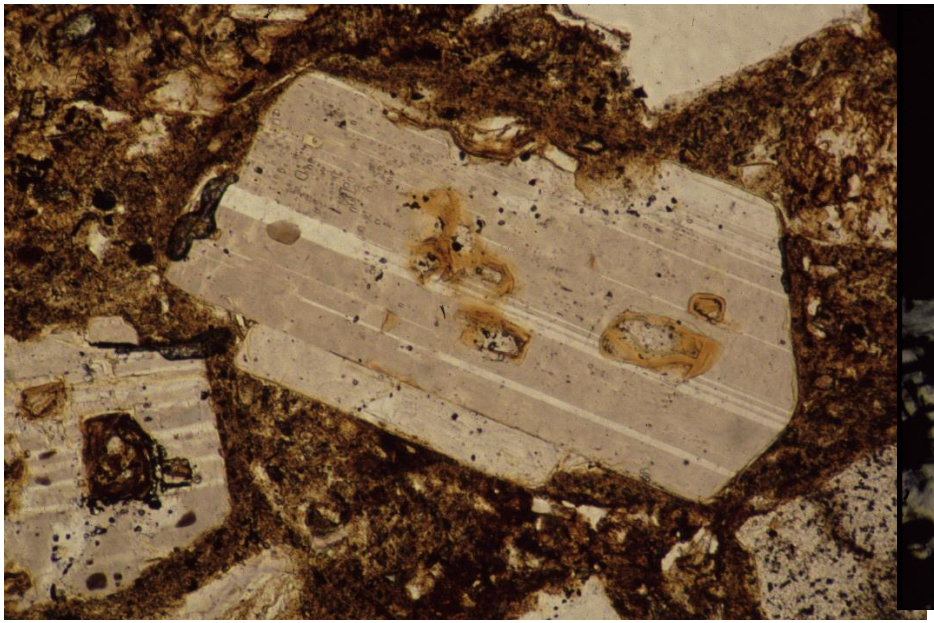
Applications in soil classification

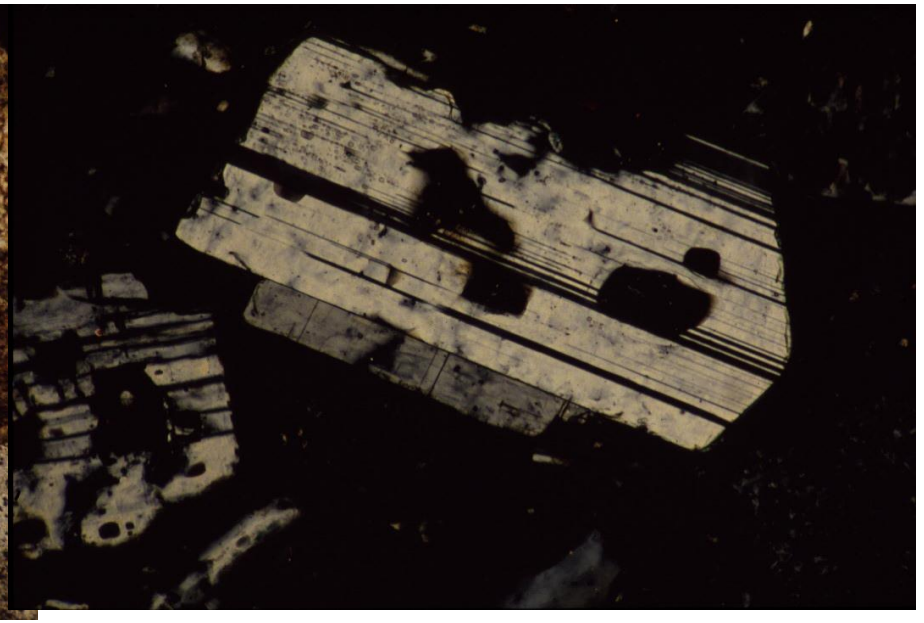
- Soil classification of Kubiëna (genetic)
- Soil Taxonomy, FAO, WRB: non-genetic
  - micromorphology is not a criterion (except formerly for argillic diagnostic horizon, partly for cambic),
  - but micromorphological studies sometimes used to support new definition proposals

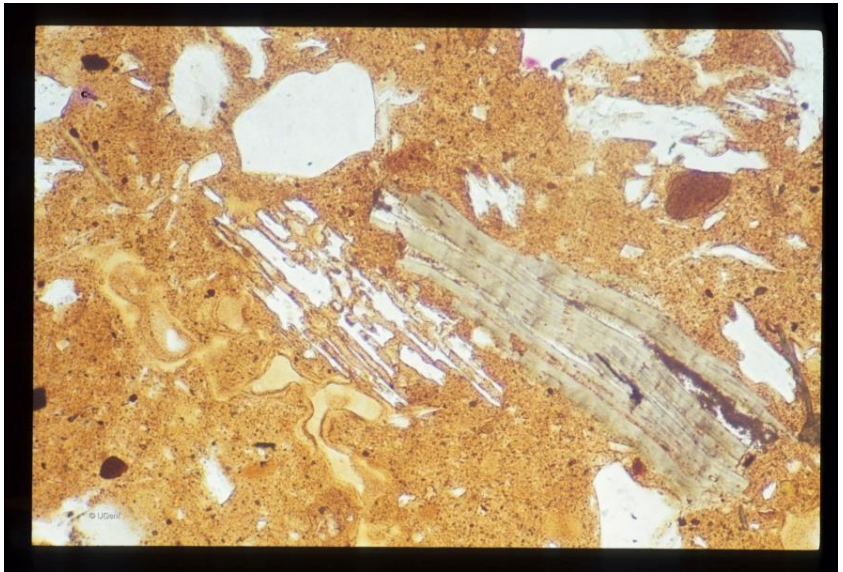
Applications in soil mineralogy

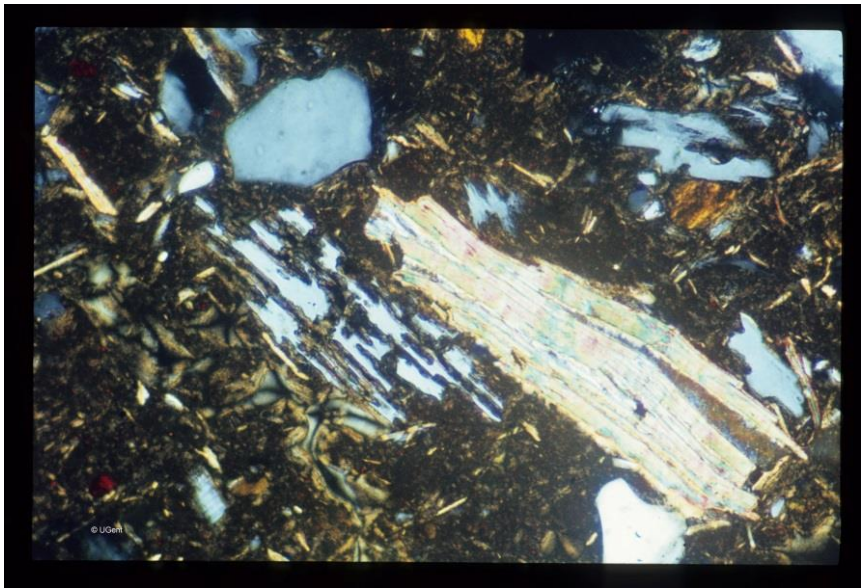
- Reconstructing the parent material including moldic voids)
- Weathering: relation between lithogenic and pedogenic minerals (e.g. garnet → goethite)
- Soil material is heterogeneous: where did neoformation take place? Examples of calcite, celestite and transformation gypsum → calcite)
- Mineral equilibria (in saprolite, in bog ore): paragenes?
- What is the chronological relation?
- Check laboratory results on bulk samples

Not all feldspars are equal!

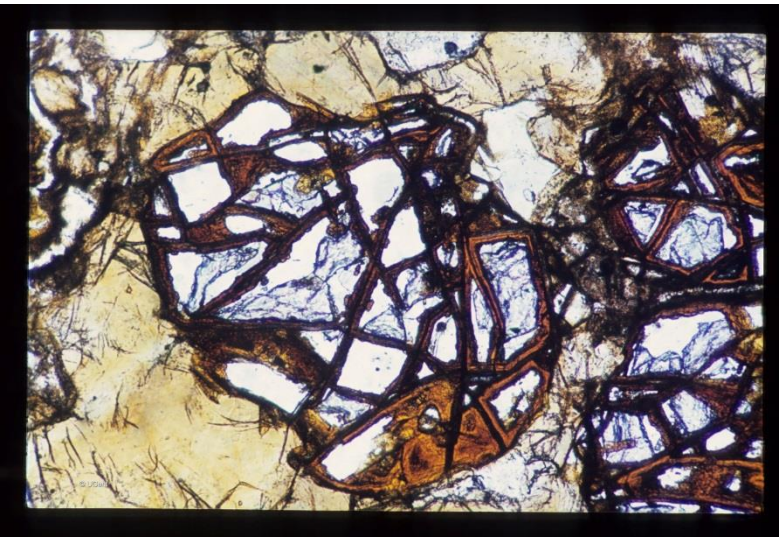


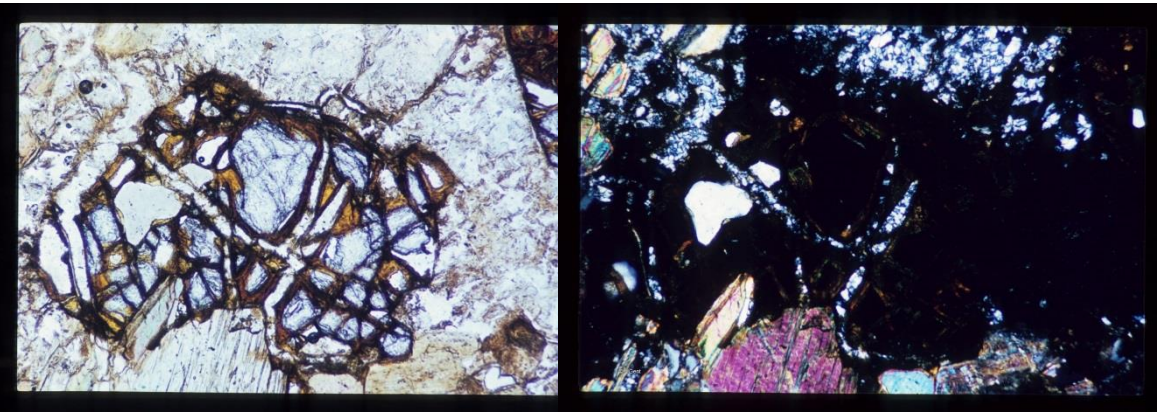


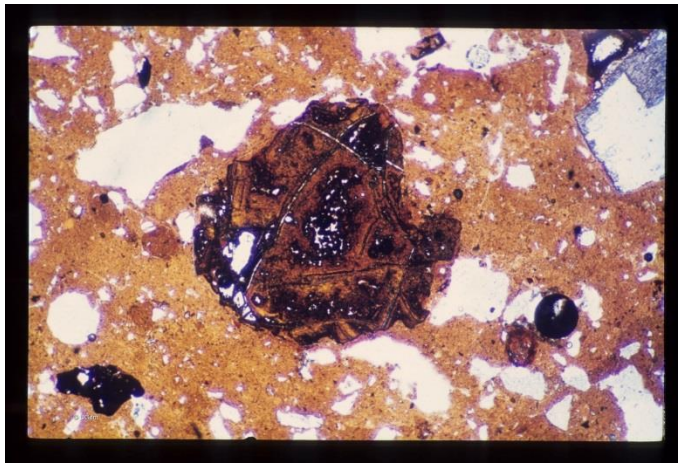




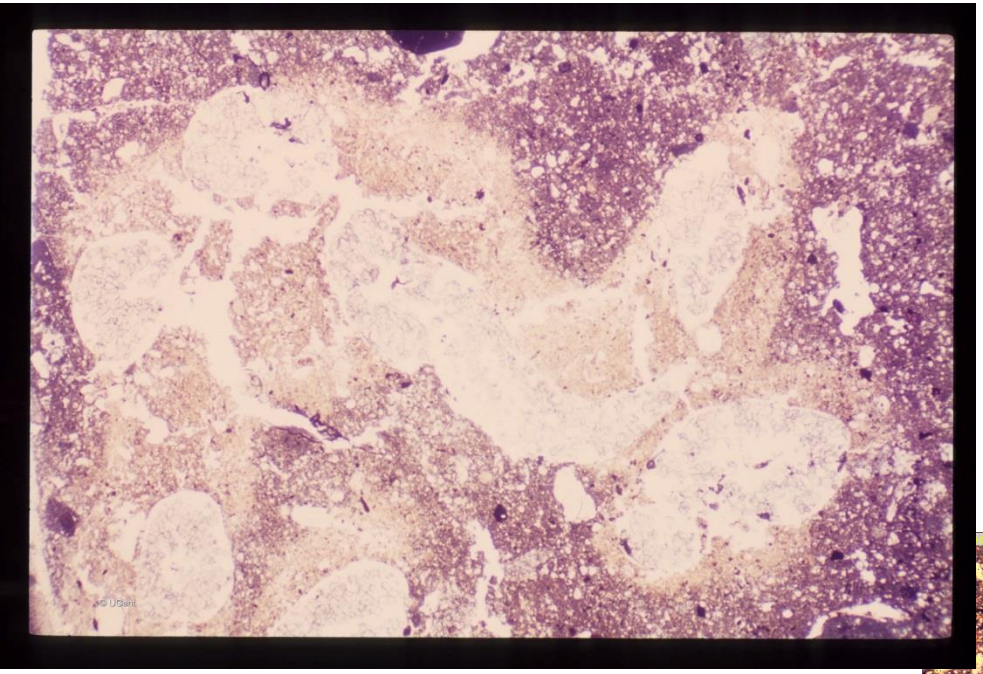
Garnets and their alteromorphs

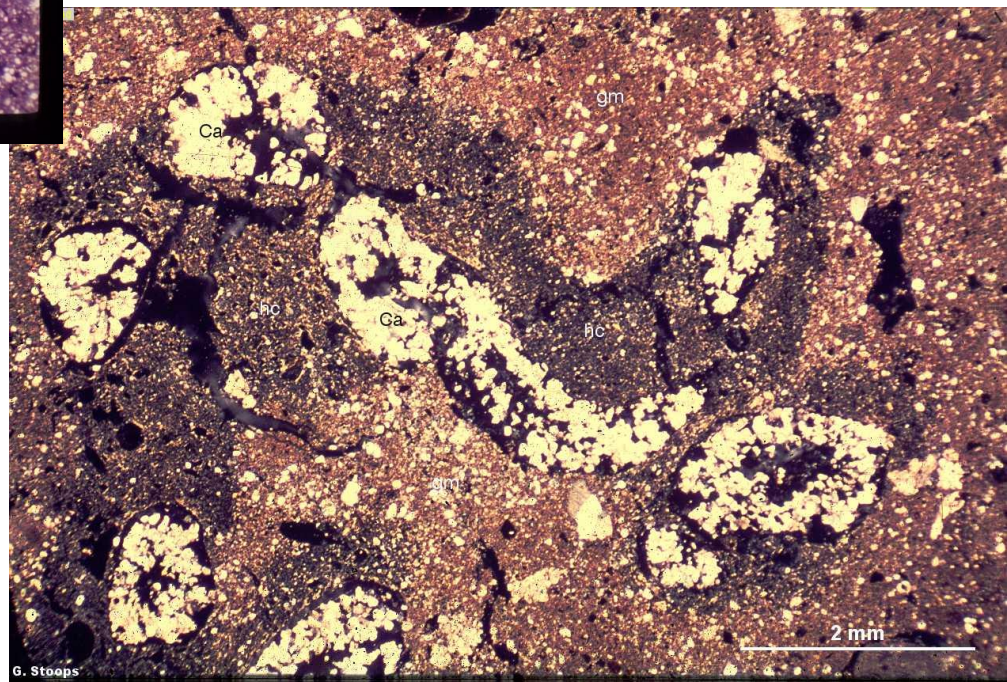




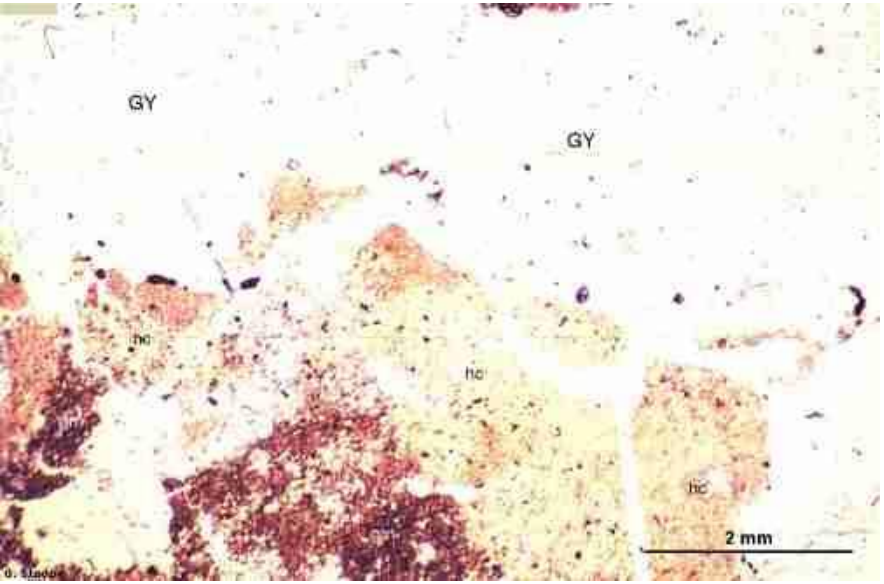


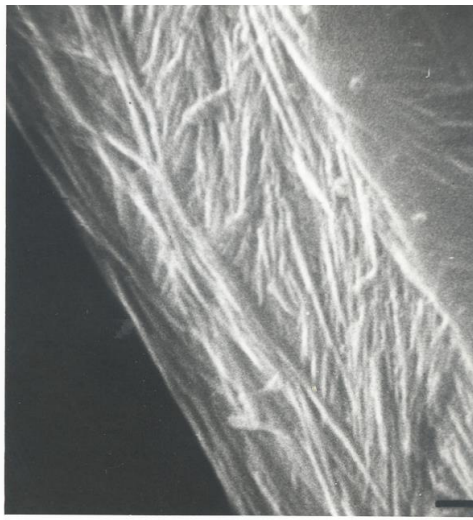
Calcite neoformation (querra)



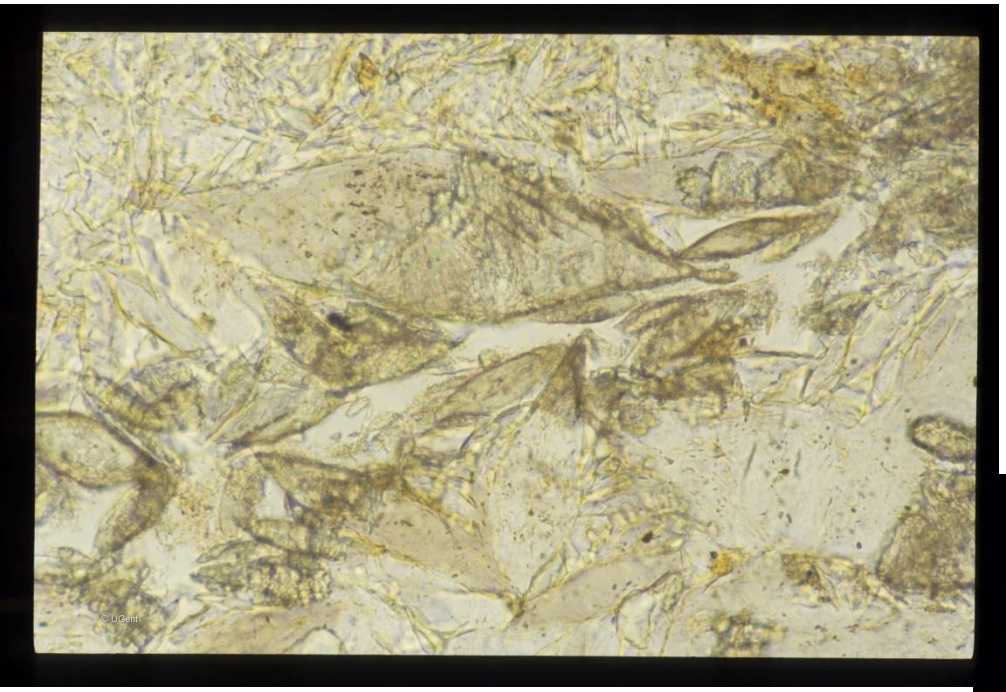


Gypsum, celestite ($SrSO_4$) and palygorskite

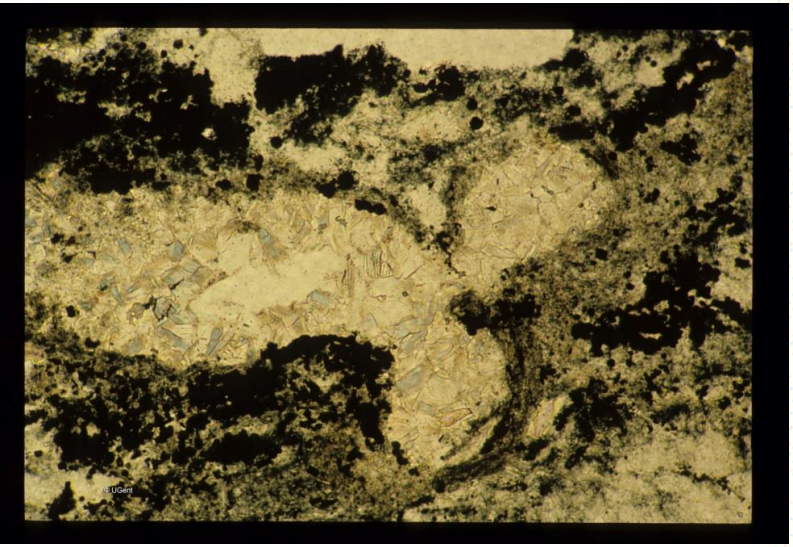


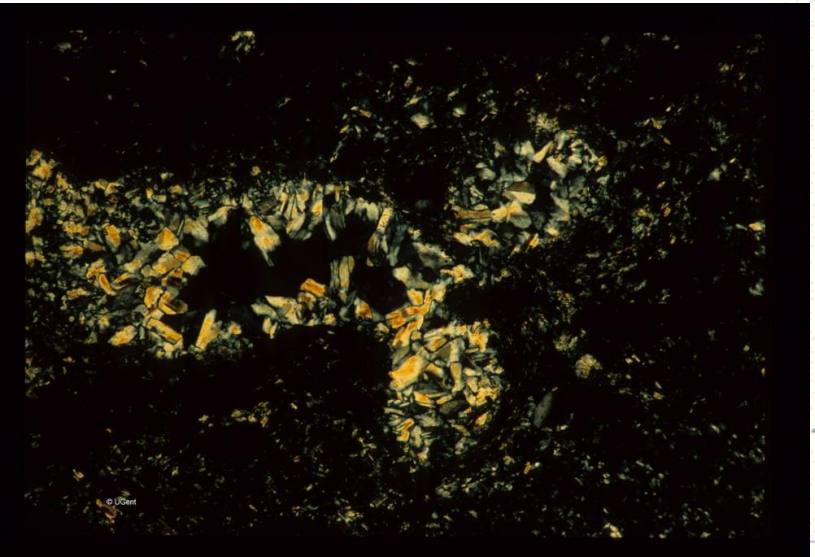


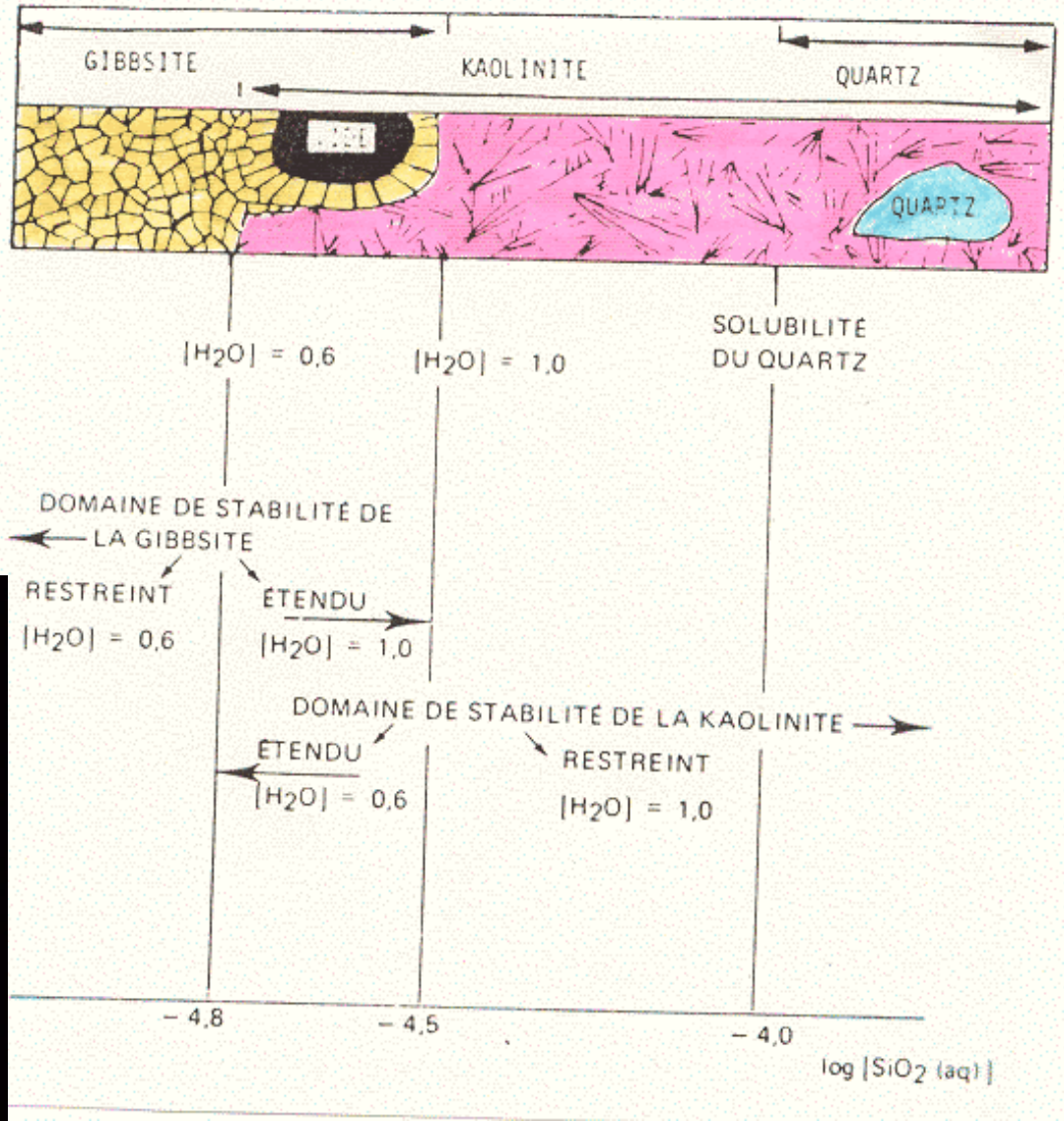
Gypsum → calcite



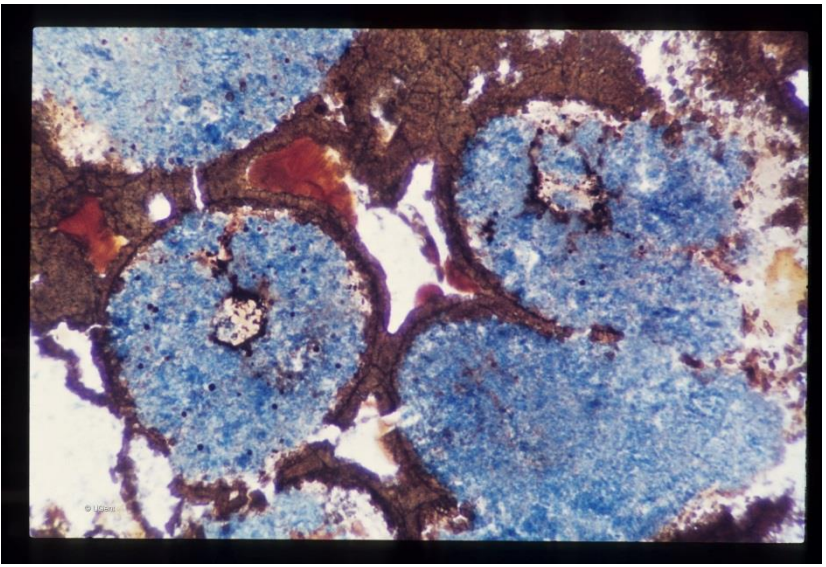
Global thermodynamics >< microreality

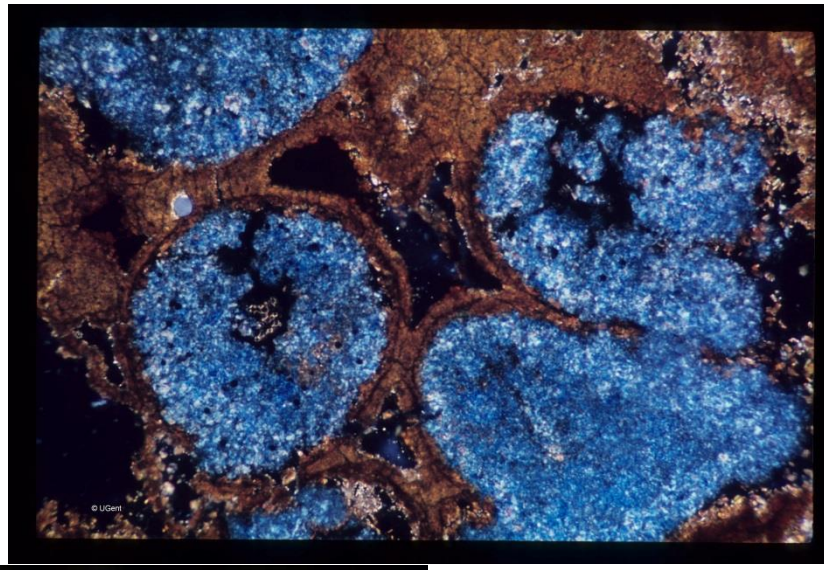


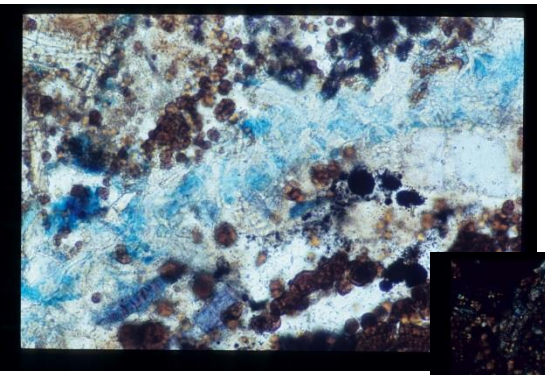


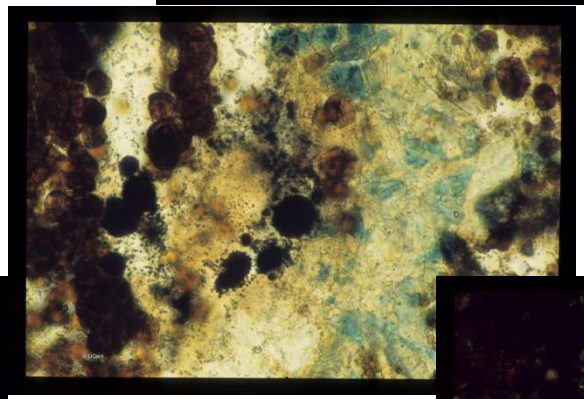


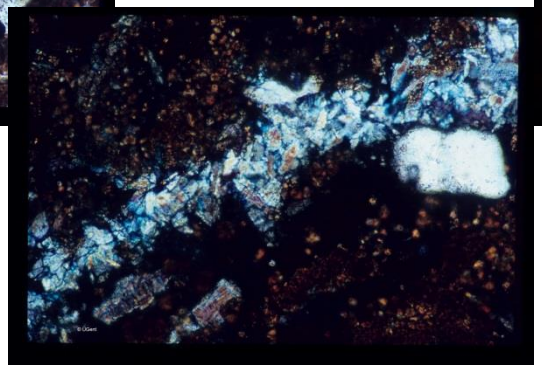
A paragenesis in bog ore?

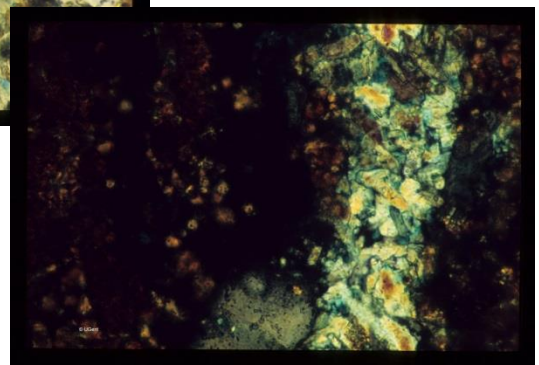




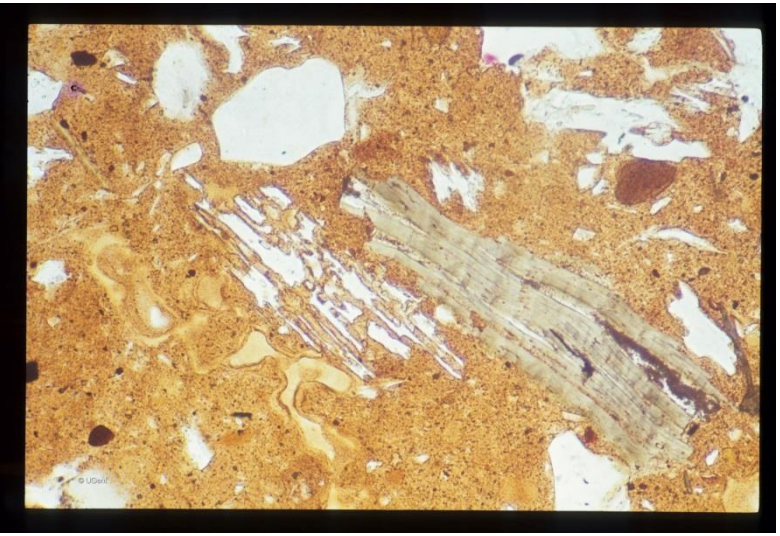


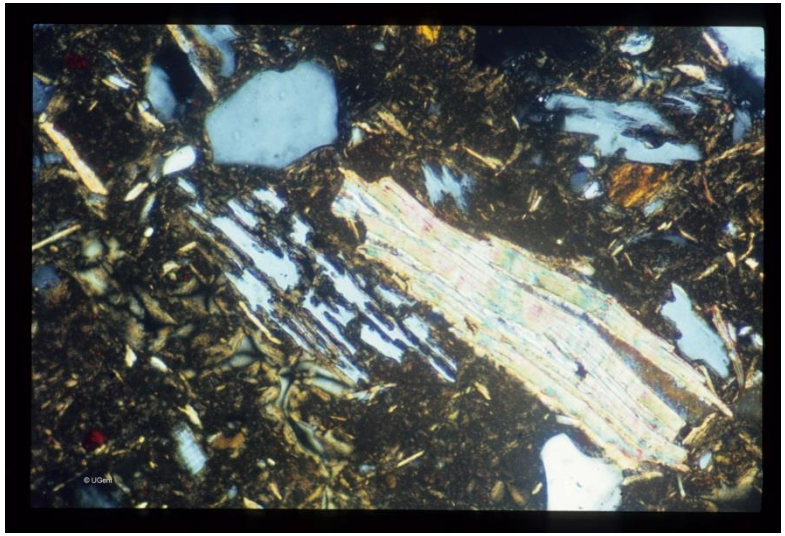


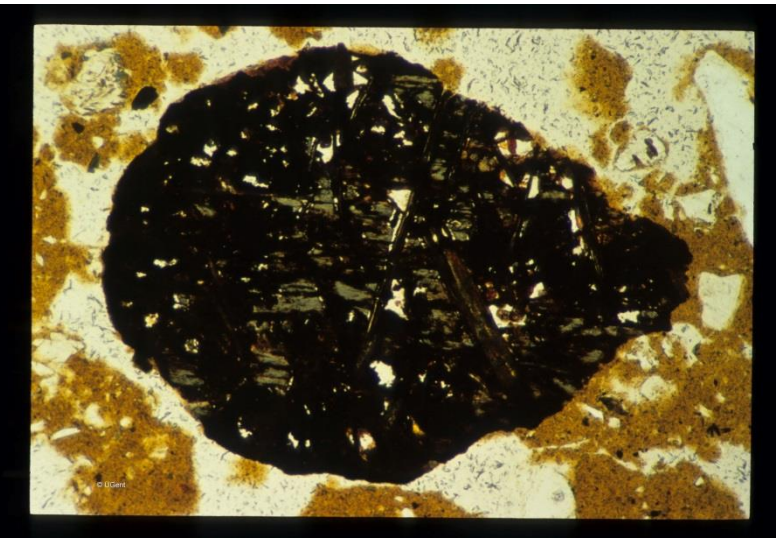


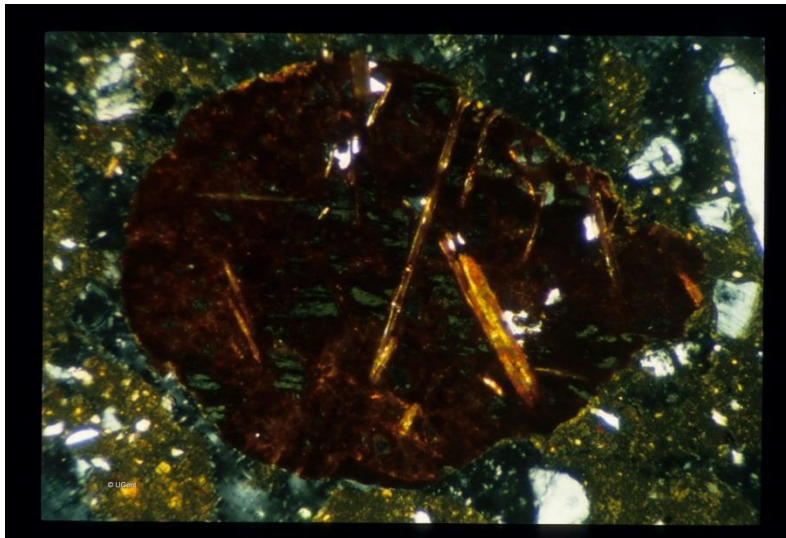


Check interpretation of laboratory results









Applications in agriculture

- Limited
- Soil physics: permeability (quantification), qoil degradation (e.g. compaction), soil crusts (sedimentary, structural, biological),
- Soil biology: influence of mesofauna
- Plant growth: interface plant – soil
- Soil chemistry: dissolution fertilisers; location of nutritive elements (e.g. in coatings >< peds))

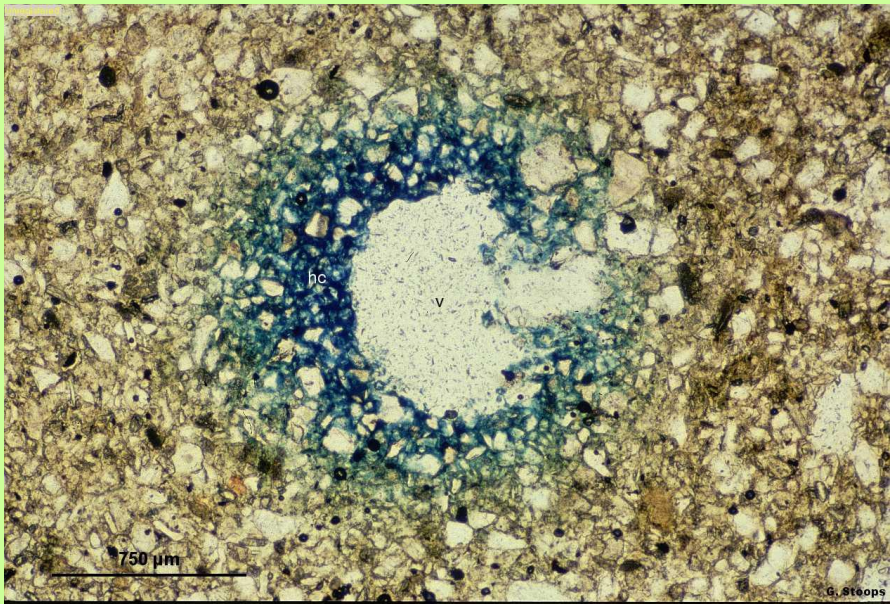
Soil science and pedology

- **The soil that supports us**
- Physical conditions: permeability, aeration, water holding capacity…
- Chemical conditions: P,N,K, trace elements…
- Can this approach be sustainable without knowledge of genesis?

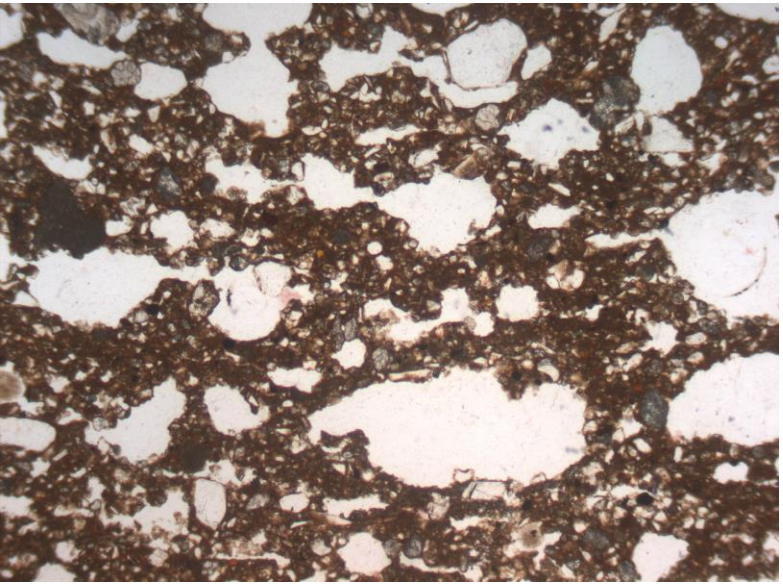
- **Soil as a natural body**
- Genesis: how was the material formed, how was the soil formed, how will it evoluate?

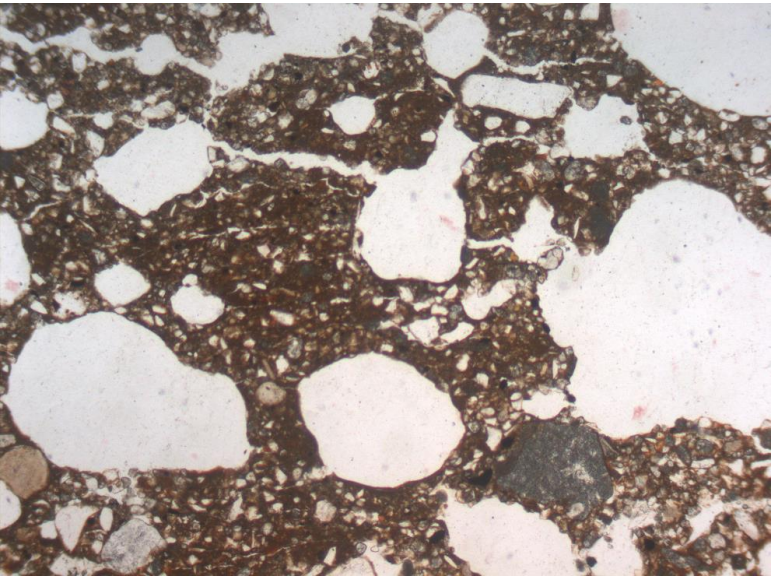
Applications in soil physics

- Studies on crust formation
- Mapping conducting voids
- Determing types and quantities of voids (micromorphometry)



Vesicular crust formation





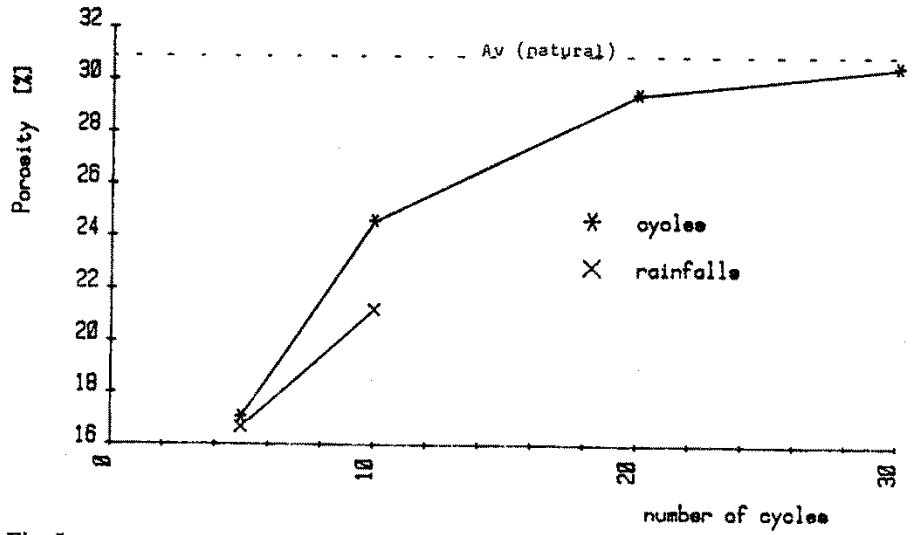


Fig. 5.
Porosity (in %) versus number of wetting cycles.

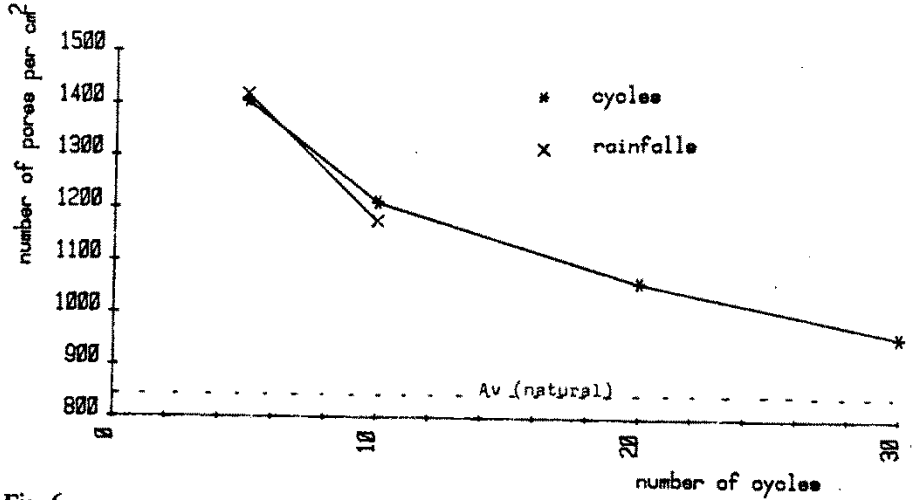
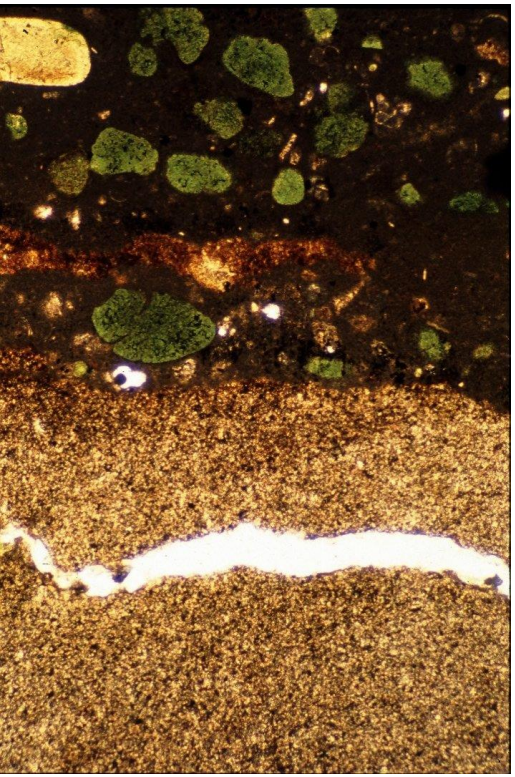


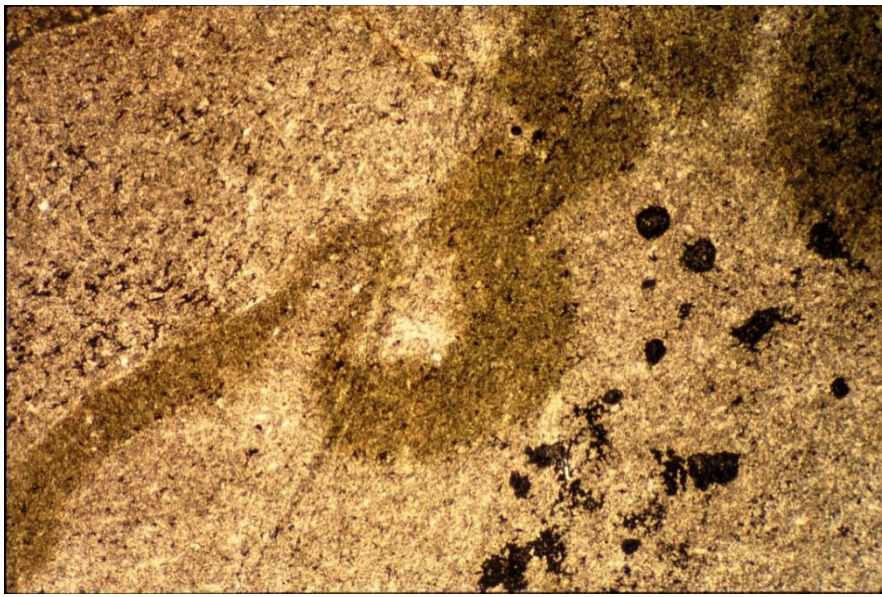
Fig. 6.
Number of pores versus number of wetting cycles.

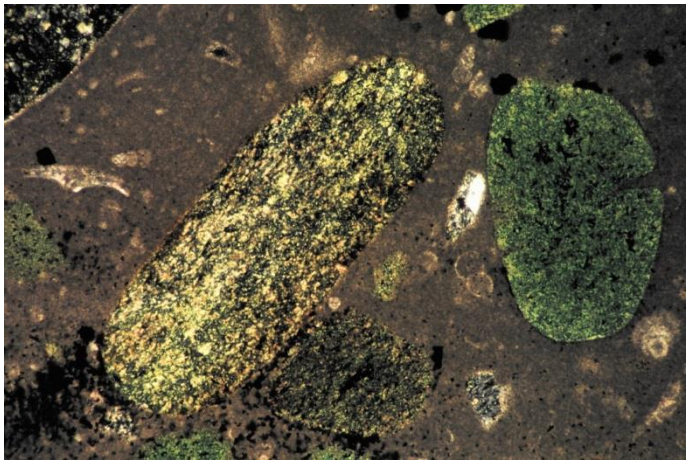
Palaeopedology

- Based on knowledge of present soil genesis
- But additionally:
- Diagenetic features
- Different environmental conditions in the geological past

Glauconite formation at top of buried palaeosoil





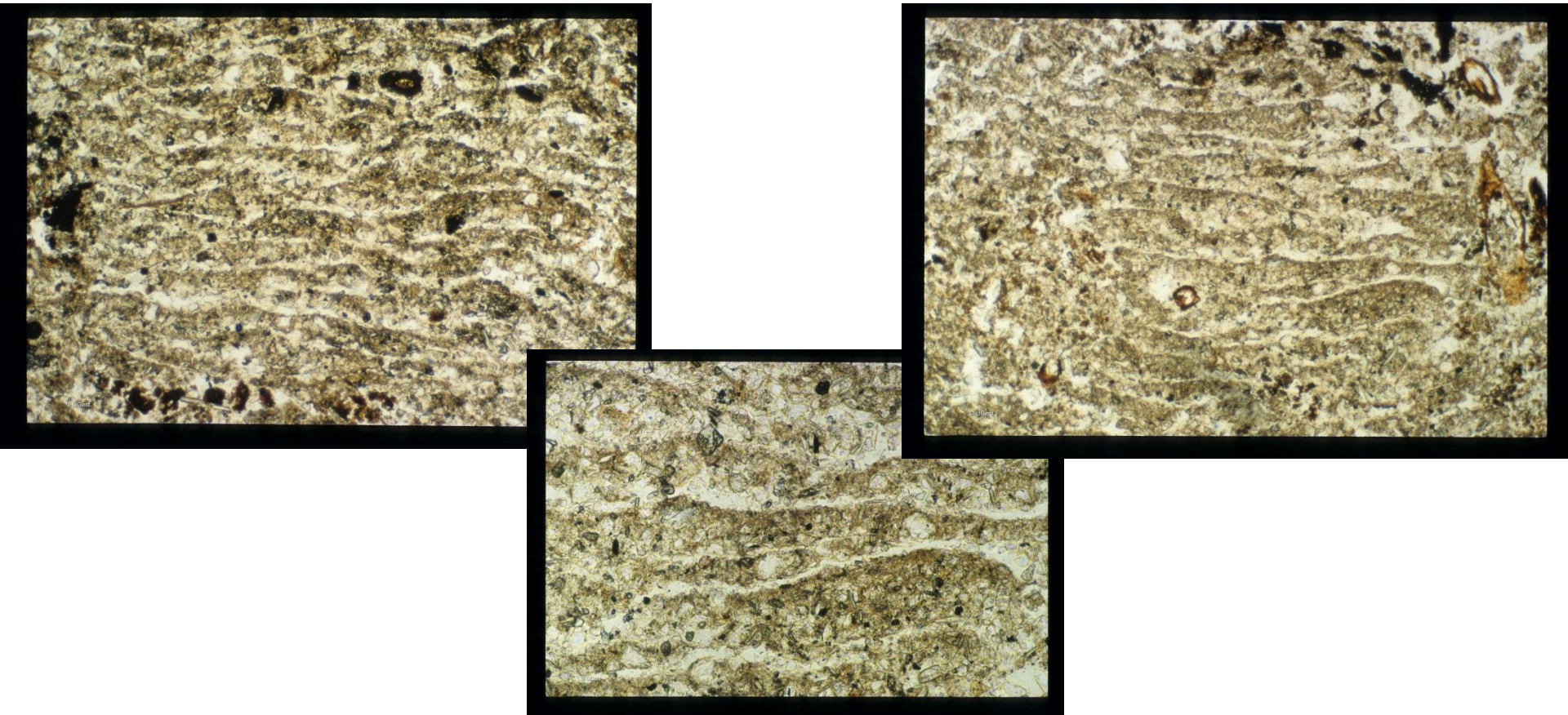


Applications in Quaternary geology

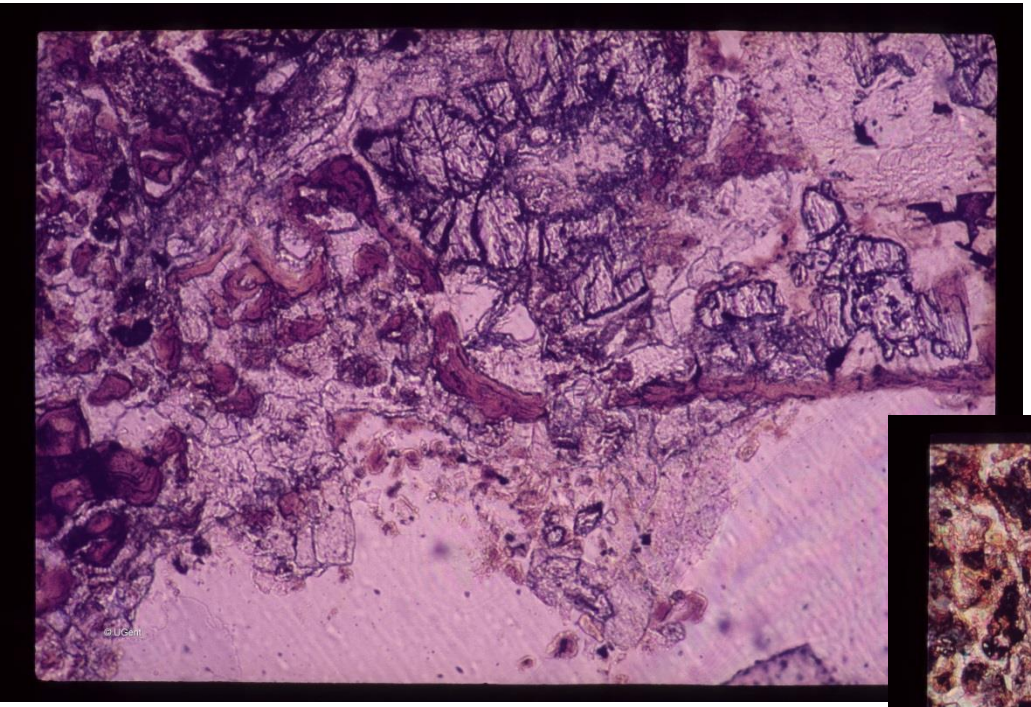
- Palaeosoils as markers for evironmental changes
- Geomorphology, erosion (including experimental work); colluvial deposits
- Sediments, especially glacial

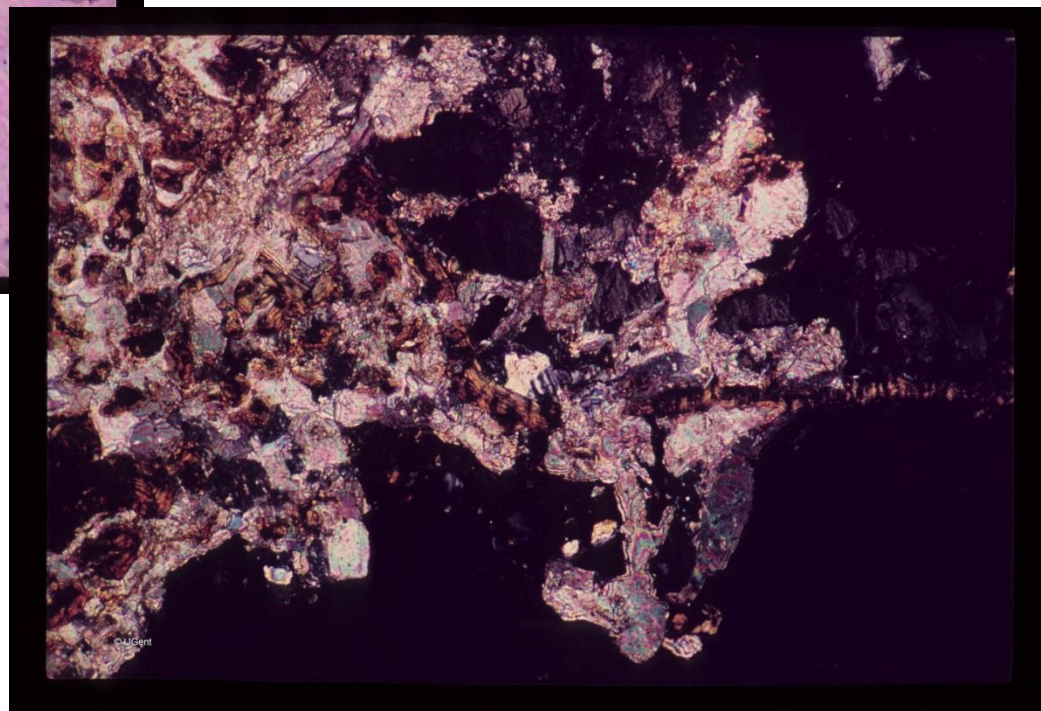
Quaternary geology

- Lenticular microstructure pointing to freeze-thawing conditions (note anisotropy)

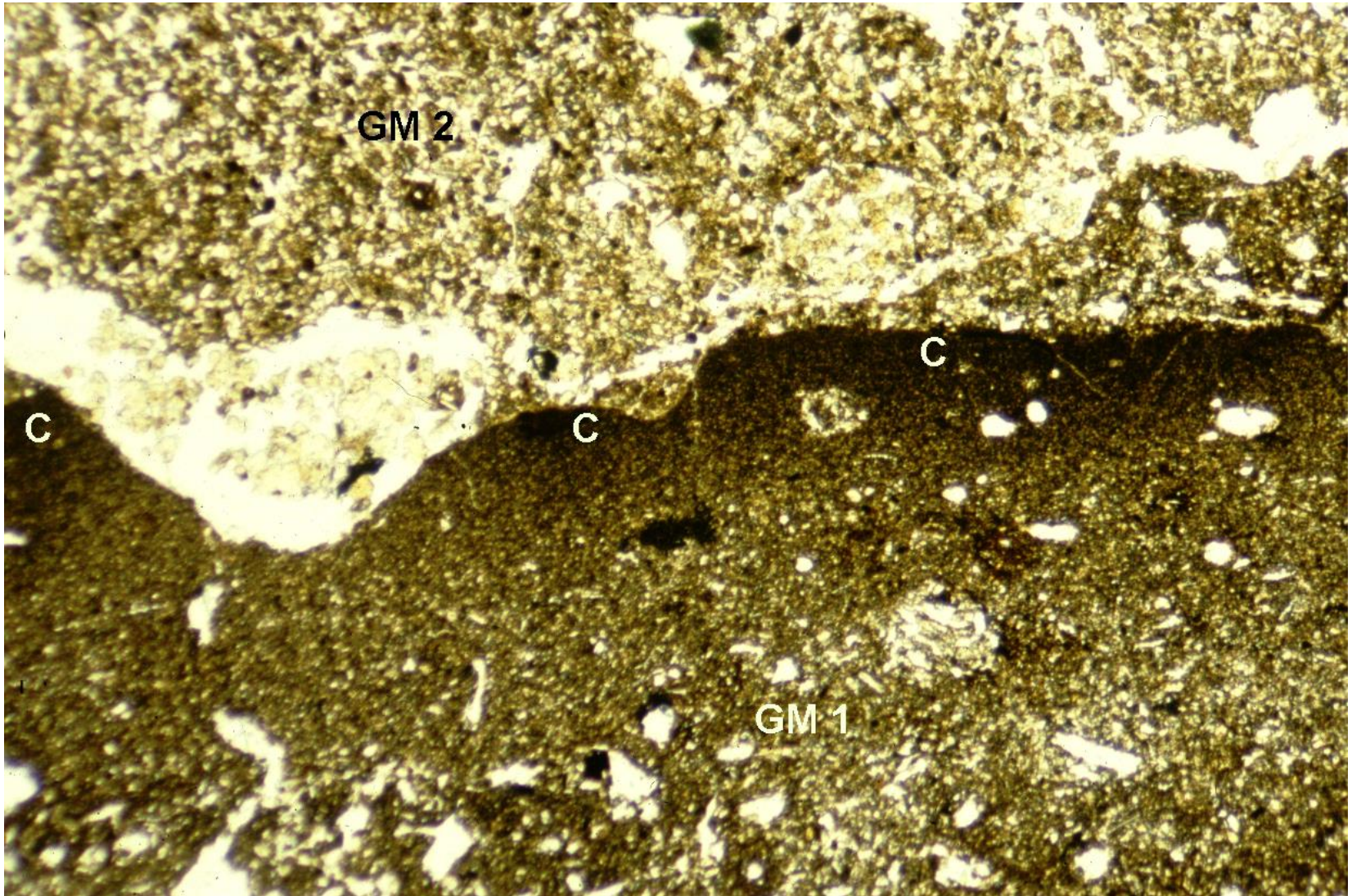


Change of environment





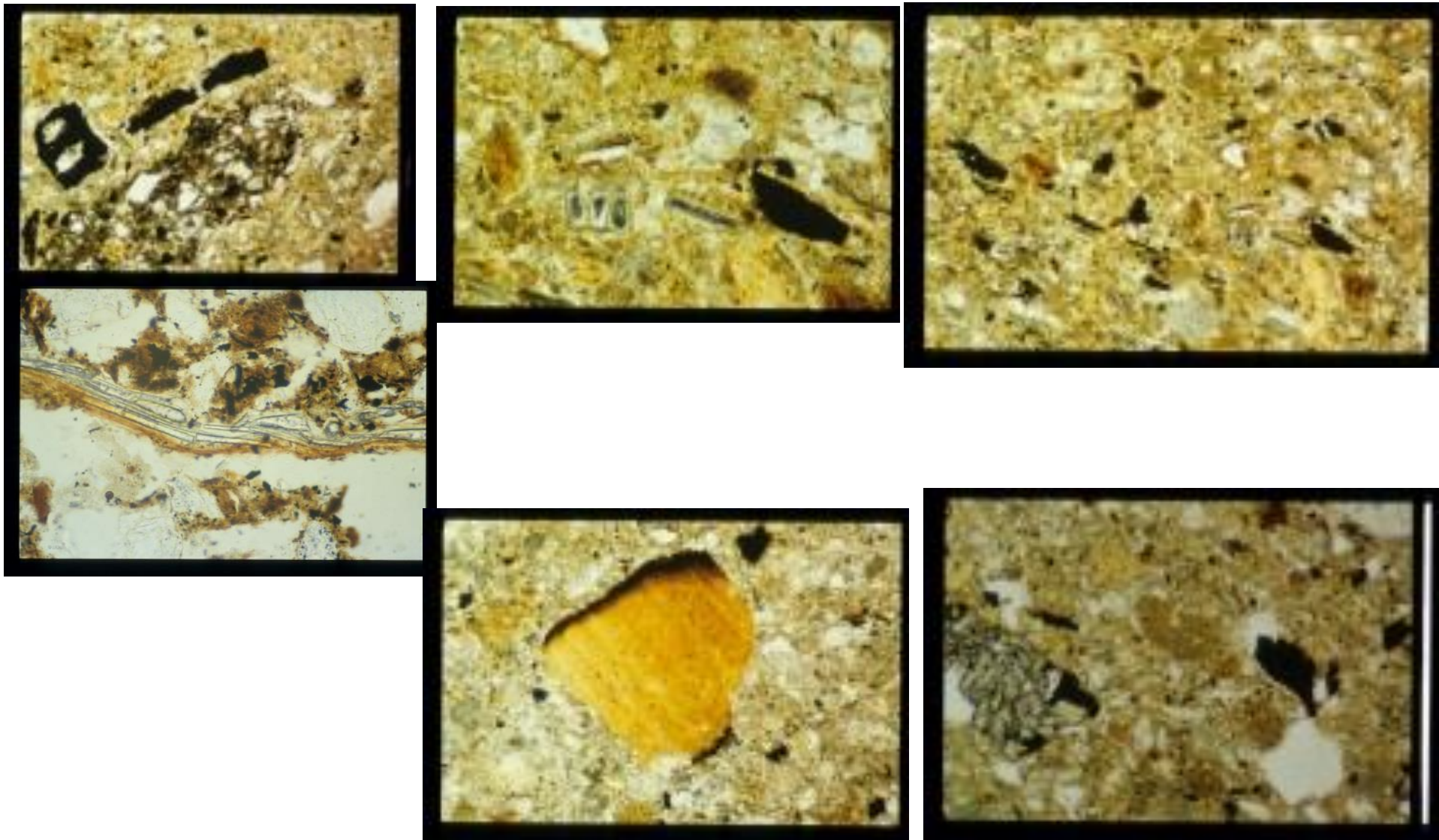
Buried crust in Pampa loess



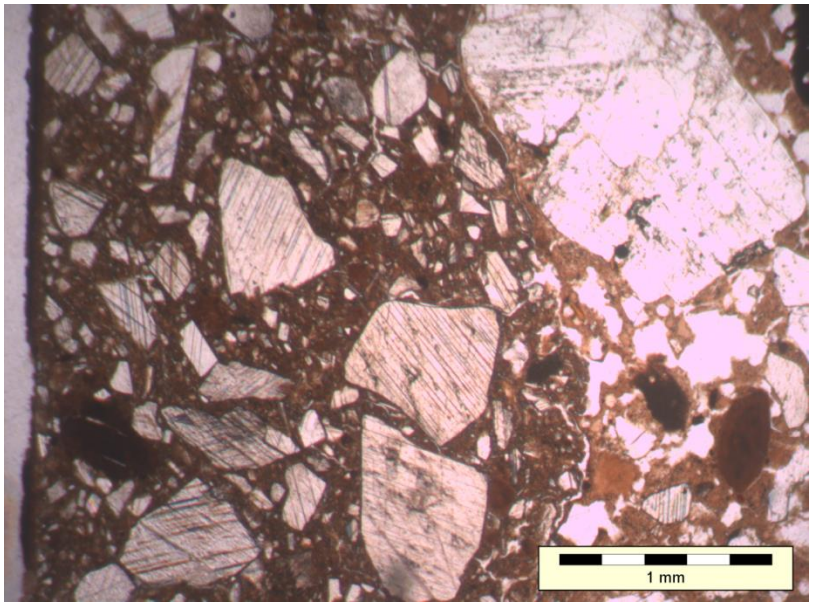
Archaeology

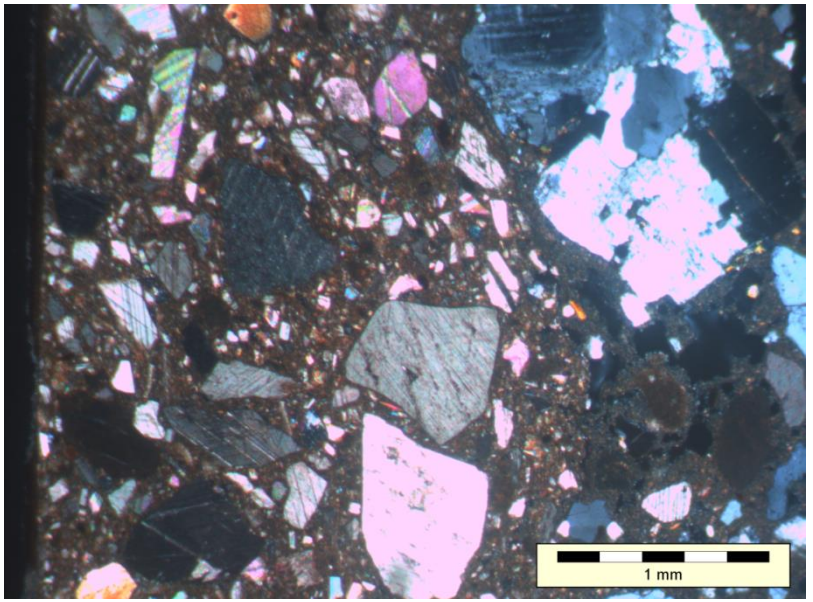
- Recognising materials (e.g. plant ash, combustion features, burned surfaces, bones, ceramics, excrements of herbivores, carnivores, omnivores, etc.
- Recognising fabrics: dark earths, trampling, forest clearance, middens, living floors, etc.

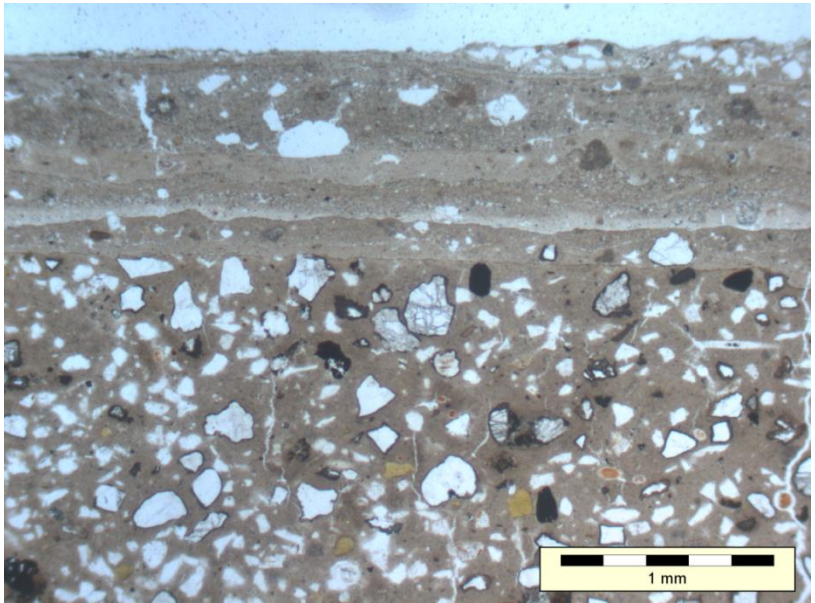
Examples from Tell ed Deir (Iraq)

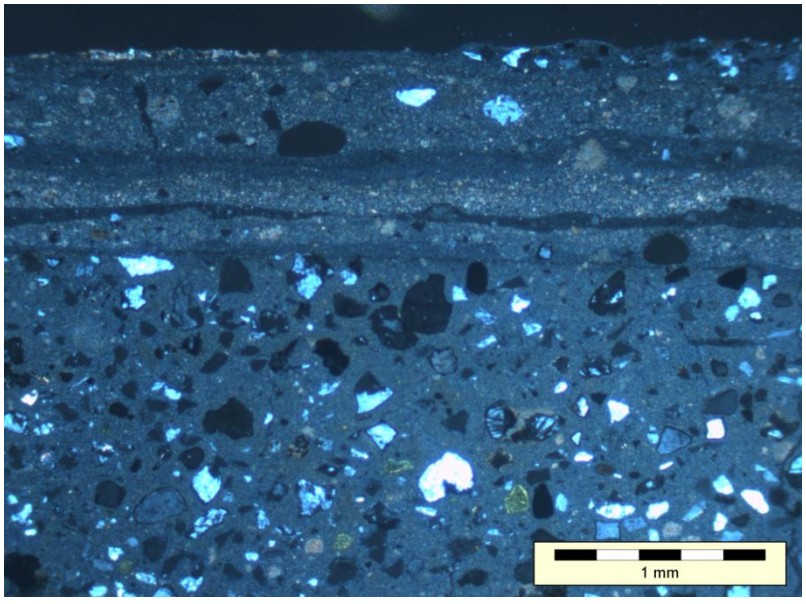


Stucco



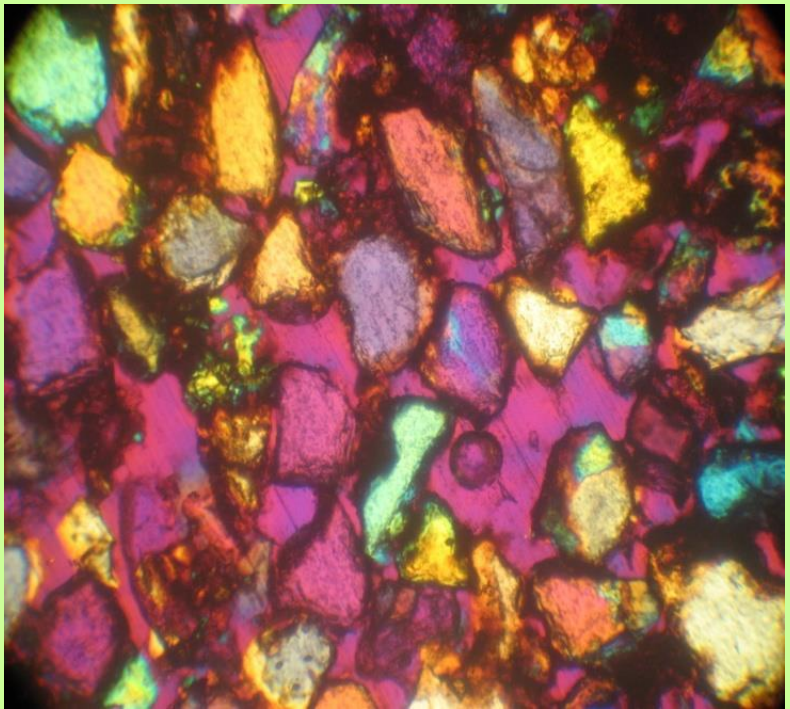


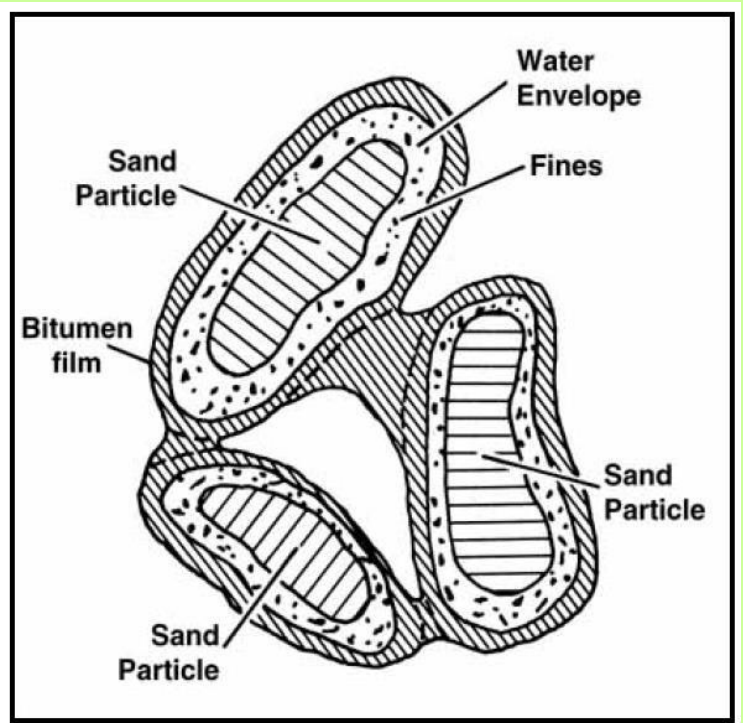




Material studies

- Studies on shearing in soil mechanics
- Application to reservoir rocks in petroleum research (J. Bell)



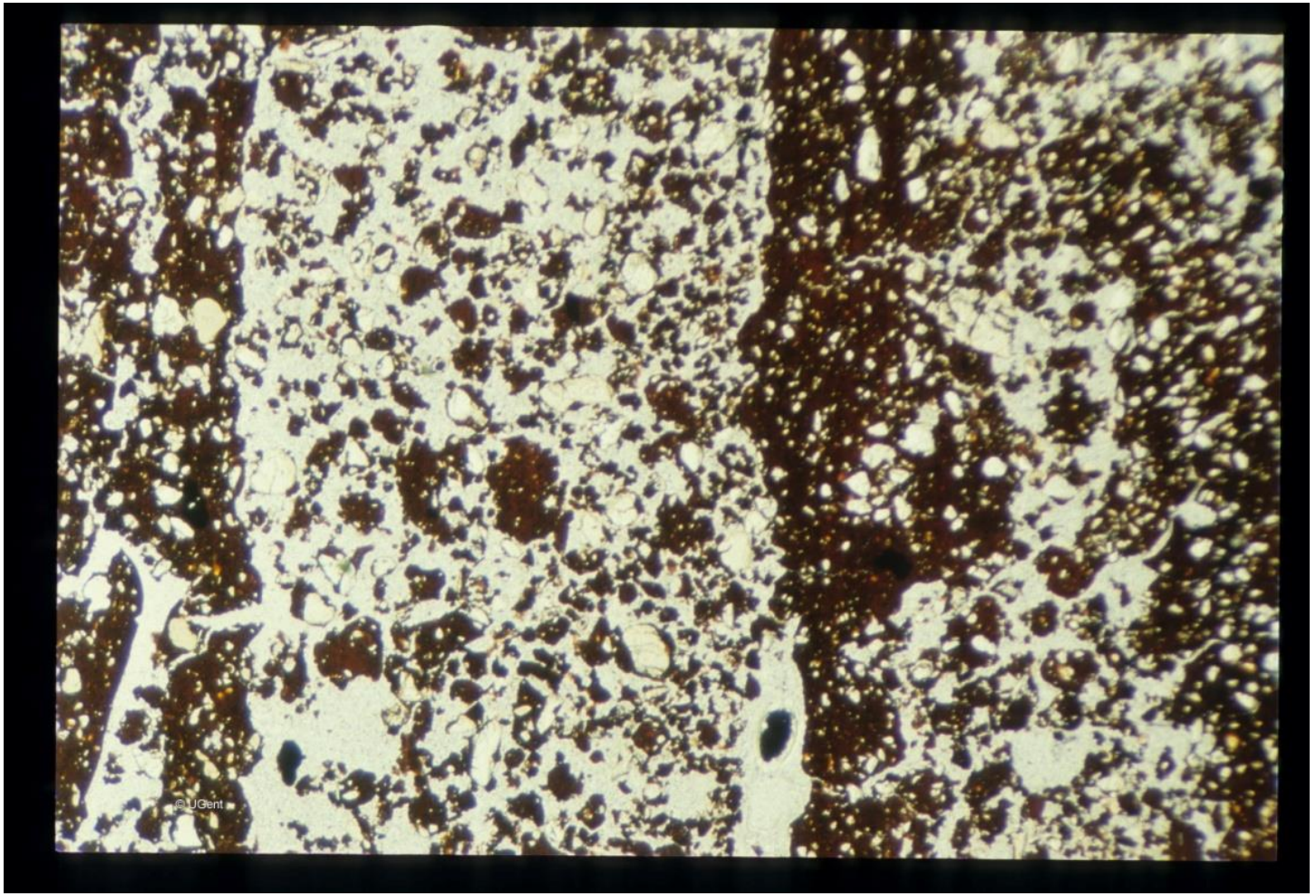


Quantification

- **Types**
- of solid constituents (e.g. by point counting): clay coatings, calcite new-formations, shear orientations
- of microstructures (e.g. by image analysis)

- **Problems:**
- Features should be mutually exclusive
- Statistically representativity needs large number of samples and thin sections
- Magnification and setting of thresholds not standardised → results cannot be compared

Mutually exclusive?



Use of micromorphology

- Soil genesis
- Soil classification
- Soil mineralogy
- Soil physics
- Soil chemistry, fertility
- Quaternary geology
- Archaeology
- Engineering etc.

What is happening?

- Shift from pedogenesis to Quaternary geology, and especially to archaeology
  - Parallel to decreased interest for genesis in soil science
- Important micromorphological centres are closing, other are emerging
- Need

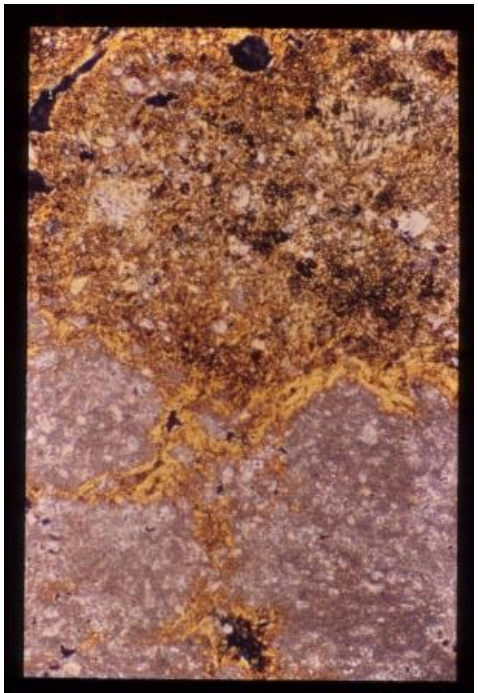
What to do?

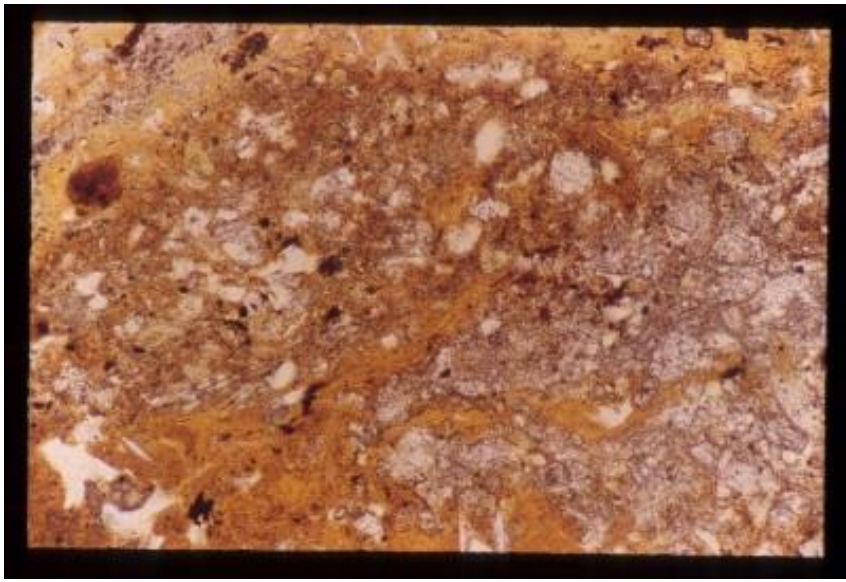
- Need for good training courses , including basic training in mineralogy and petrography for non-geologists
- Need for more experimental work (already started in archaeology, in the past also in erosion studies)
- Need for more interdisciplinary work
- Need for more interaction with soil scientists working in agriculture

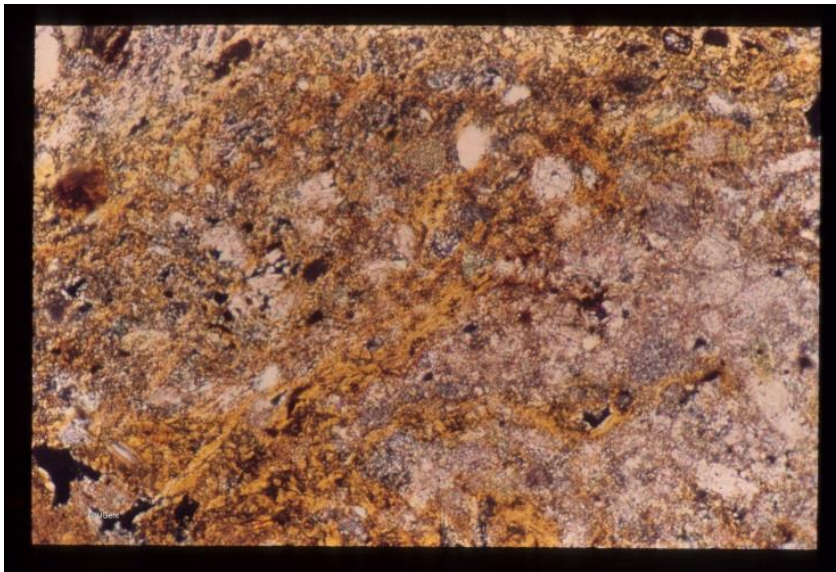
CONTENT

- Introduction
  - Definition and history
  - Mutual relations
  - Quantification ?
- Contributions to
  - Soil science
  - Quaternary geology, including Palaeopedology
  - Archaeology
- Conclusions

Weathering of chalk to clay with flint







Weathering of chalk to clay with flint