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Mechanics of Natural Solids - a symposium in Horton, Greece

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Like Atkinson's 'What is the matter with geotechnical engineering', wherein EC7 is blamed, the present pamphlet could be entitled 'What's up with geomechanics'? There is no Eurocode for geomechanics which could lead to a loss of reality. There is a plethora of open questions with natural solids - soil, rock, snow and ice -, apparently too complex for a symposium. Presentations and discussions indicate a unfied energetic approach, this success can be attributed to the creative spirit of Horton.

Tal como lo dicho por Atkinson ¿qué le pasa a la Ingeniería Geotécnica?, culpando al EC7, el presente panfleto podría ser titulado ¿qué pasa con la geomecánica?. No hay Eurocódigo para la geomecánica, lo cual podría tender a una pérdida de realismo. Existe una plétora de preguntas abiertas relativas a sólidos naturales – suelo, roca, nieve y hielo -, preguntas aparentemente muy complejas para un simposio. Las presentaciones y discusiones indican un enfoque energético unificado, este éxito puede ser atribuido al espíritu creativo de Horton.

Aristoteles defined the difference of granular and continuous matter by the reaction to *energeia* (Triantafyllidis found this statement), which presumably meant shaking (*i.e.* seismic action). Ever since scientists try to understand the energetics of granular and solid matter in nature. Sand is apparently a simple representant, but would you expect that:

- the city of Volos collapsed in 1956 as its foundations sunk into fine sand by an earthquake,

- a gas production tower off Borneo disappeared in sand when methane rose near the borehole,

- a submarine avalanche was triggered when building the Airport Saint- Laurent-du-Var and caused a tsunami that killed 20 persons,

- a TV tower, built in Moscow with a plate on dense sand, tilted repeatedly in storms and turned back with settlement in normal wind?

Clay is a likewise familiar matter, but one can hardly explain why:

- plates of clay upon sand along the Corinthian Gulf slid seawards after strong earthquakes so that the ancient capital Eliki drowned,

- craters off Patras arose in marine clay above a fault with tidal currents during the 1995 earthquake,

- huge masses of clay arose from faults to the sea floor after the big 2004 Sumatra earthquake,

- an avalanche of mud and boulders rushed down in 1964 from Mt. Huascaran with *ca.* 300 km/h and erased a town with 20.000 inhabitants,

- temples in Japan survived earthquakes upon a cushion of clay with saturated sand which screened shear waves repeatedly,

- the Kansai Airport island off Osaka upon clay settled unevenly by more than 3 m after its completion.

Coulomb founded soil mechanics in 1776 by proposing shear bands with friction and cohesion in such directions that kinetic energy starts to arise (later he turned to electric charges). His theory is used by engineers until present, but the energetics could not be clarfied and with it cases as indicated above cannot be explained. Maxwell (who unfied the theory of electromagnetism) remarked that thermodynamics do not suffice for sand as this has a 'historical element'. Recently Kadanoff, who explained "critical phenomena" (*i.e.* pattern formation and deterministic chaos) for thermodynamic systems, declared that an energetic extension for sand would hardly be feasible. The issue becomes more complex with rock in the lithosphere, and also with snow and ice although this is only H_2O and can be transparent. One cannot predict reliably when and where:

- a cliff along the sea, a lake or a river will fall again,

- folds, faults or cracks arise and disappear by the deformation of rock and ice masses,

- boreholes in the earth crust close slowly or suddenly,

- gas breaks through deformed sealing layers in faults and produces rising mud,

- snow and ice flow and break like soil or rock even if the temperature is close to the melting point.

The *geomechanics* of soil, rock, snow and ice is often differently treated by engineers, geologists, geophysicists and glaciologists. For lack of a unied physical concept a Babylonic confusion arose repeatedly among these disciplines. The literature is spoiled by a morass of equations and a jungle of data. Eforts with brutal force failed, for example:

- a supercomputer in Japan named "Earth" did not produce more insight,

- the announced clarification of earthquake source mechanisms ended with a big loss of money,

- large field tests led repeatedly to a mess of data or even to an unexpected collapse,

-mammouth conferences produced confusion or even regression instead of progress.

So it appears very ambitious that two professors of geotechnical engineering, D. Kolymbas from Innsbruck and G. Viggiani from Grenoble, invited 40 scientists for a symposium on the "Mechanics of Natural Solids" from September 7th to 9th 2009 in Horton, Greece. The speakers were engineers, geologists and physicists with experience in soil, rock, snow and/or ice. The participants had ample time for discussion and were encouraged to overcome the Babylonic confusion in favour of mutual understanding and insight. This worked beyond optimistic expectations and may be illustrated by a brief anthology.

A theory for sand named hypoplasticity was founded in 1977 by Kolymbas and improved gradually so that it covers a plethora of observations. It is now supported by a novel physical theory which extends thermodynamics by means of the heat-like seismic energy. This explains the onset of catastrophies where the free energy is at the verge of concavity - imagine a bowl with a convex rim and a little sphere therein, when you tilt it too much the sphere can no more find an equilibrium. The free energy is due to gravity (as for a sphere in the bowl), elasticity (think of jammed grains or blocks), changing solid surfaces (you need more energy to break a drystone than a wet one), ordered and disordered motion (kinetic and heat-like seismic energy) and is lost into heat. The self-healing of towers (*i.e.* turning back and re-densication) occurs in the stable concave range if thus the free energy is more rapidly reduced by shaking (seismic activation).

Further contributions to the symposium indicate that this energetic concept could also explain critical phenomena at the verge of concavity. Then a further shearing is localized to narrow bands with mutual granular rotations, a further extension is localized in cracks, and the seismicity (audible by acoustic emission) grows suddenly. This cannot only explain Coulomb's theory, but also the genesis of fault patterns and earthquakes in hardgrained parts of the lithosphere. The known similarity of fault patterns in sandbox tests and in the earth crust is thus supported by an objective theory (Figure 1).

Figure 1: Pattern of vertical shear bands in a sandbox (above) and in the field (below) (taken from Kolymbas and Viggiani 2009)

Other contributions confirm that thermal activations play a major role for soils and rocks with soft minerals or for extremely long times, and are dominant near the melting point of ice or rock. Depending on activation energies, dislocations in crystallites and heat determine both the viscoplastic flow and the propagation and healing of cracks. The borderline between flow and fracture agrees with the verge of concavity of the free energy, its approach by deformations is delayed by thermally and seismically activated relaxation. Localizations into shear bands and cracks come and go along this borderline. Engineers speak of flow equilibria and geologists of cataclastic flow, there is a perspective now for judging energetically when such cases become catastrophic.

Critical phenomena in natural solids are more complex with pore fluid and dissolved substances therein. The genesis of cracks in clay was explained in a novel way. The cavitation starts by a positive feedback at surface dimples, crack distances are determined by the rate of evaporation or of compacting filtration. This confirms what farmers and potters know, and can be extended to dams and parts of the earth crust. The counterpart of such pattern formations is the catastrophic chaos if soil or rock dilates withtaking up water so that inner erosion leads to mud flow and cold volcanism.

Thus some common features of pattern formation and deterministic chaos in the litho - and pagosphere are now better understood (Figure 2). The energetics plays the key role, evolutions are seismically and thermally activated, critical phenomena occur with localizations at the verge of stability.

The spectra of patterns and emissions are rather fractal (similar to coastlines by erosion at different scales), but we are still far from equations which reflect fractal mechanisms. Quantifications for cases as indicated further above will need years of hard work, but the perspective is better now.

During the symposium the pianist and musicologist George Hadjinikos gave a recital. Thus the participants were aware that their work has a lot in common with music. Good science is like a symphony, it needs inspiring surroundings and society. Bad science means cacophony, it results from noisy surroundings and inadequate pressure. The symposium in Horton is a convincing counter-example against pseudo-scientic efforts. Ancient Greeks founded Science by discovering the productive dialogue (from the Stoa to Socrates) and the stringent analysis and synthesis (Aristoteles). They understood the interplay of inspiration and logic which together constitute the human spirit. They understood

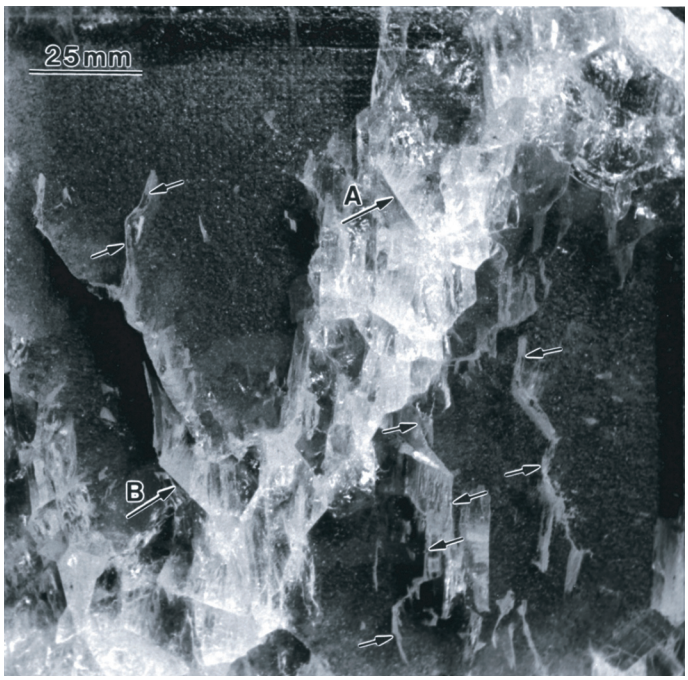

Figure 2: Pattern of ice cracks in a lab test (left) and in the Arctic sea (right) (taken from Kolymbas and Viggiani 2009)

the vital need of patience and peace instead of stress and brutal force. They were certainly aware that science and arts have a common spiritual root.

25 years ago Pia Hadjinikou-Angelini started with cultural events in her homeplace Horton in South Pelion (the home of Centaurs and Argonauts). Every summer internationally known artists perform music, theater and dance in a rebuilt amphitheatre and a museum which formerly served for the storage of olive oil. Pia's brother George led young musicians in seminars to the core of their art. In an exceptionally inspiring atmoshere artists and public experienced the power of human spirit in harmony with nature. About every five years a scientific symposium takes place alongside with such a cultural event, the topic was geomechanics as Pia's son Dimitrios Kolymbas works in this field.

In comparison with big festivals and conferences the Horton cultural events are quite modest, but rich by spiritual economy. The moderate financial support was never sufficient to cover all the expenses, so Pia Hadjinikou-Angelini sacrifficed part of her heritage and spent all of her energy for the benefit of arts and science. George Hadjinikos realized in depth what goes wrong in the present music industry and shows the access to true music. Ernst Mach and Albert Einstein noticed the key role of spiritual economy in scientic research. The last symposium in Horton has shown again that this kind of cultural activity is to the benefit of mankind.

References

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