岩石物理学与地质构造学前沿短期课程

清华大学周培源应用数学研究中心

10月30日 ~11月 2日，2017

时间	上课地点	课程名称
10月 30日，19:00- 20:30	科学馆118教室	The Future Impact of Rock physics and Digital Rock Physics
10月31日，19:00- 20:30	科学馆118教室	The Rock Physics Basis for 4D Seismic
11月1日，19:00- 20:30	科学馆118教室	Reconciling Crustal Faulting Complexity with Rock Mechanics
11月2日，19:00- 20:30	科学馆118教室	What's driving what: An active asthenosphere driving a passive lithosphere, or the other way?

In these 4-lecture course, professor Amos Nur will attempt to illuminate some outstanding, challenging issues in rock physics, crustal faulting, and plate tectonics. One common denominator to these lectures will be to point out the key needs for much better modelling and computing.

Professor Amos Nur was the founder and director of the Rock Physics and Borehole Geophysics in Stanford University since 1977. He has served as the Wayne Loel Professor of Earth Sciences since 1988. He was chair of the Geophysics Department, Stanford from 1986-1991 and from 1997- 2000. Professor Nur is an elected member of the National Academy of Engineering (2001), a Fellow of the American Geophysical Union (1976); Fellow, Geological Society of America (1980); He is the 2011 recipient of the Maurice Ewing medal of the Society of Exploration Geophysics.

Professor Nur is widely considered one of the world's top academic authorities on rock physics. He applies rock physics results to the understanding of tectonophysical processes in the Earth's crust and lithosphere, a major thrust of which is the role of fluids in crustal processes and in energy resources. Nur pioneered the use of seismic velocity measurements to characterize the changing state of oil and gas reservoirs as the volume of fluid in the rock changed during pumping; the process has come to be known as "four-dimensional" seismic monitoring. He has published over 240 papers and guided dozens of doctoral and master's candidates. Nur was on the Stanford faculty from 1970 until his retirement in 2008 and he remains affiliated with the school as professor emeritus.

主办单位：	清华大学周培源应用数学研究中心

课程教室位置扫码：清华大学科学馆 118 会议室

欢迎广大老师和同学报名参加短期课程。

报名请发送邮件至 sunwt@tsinghua.edu.cn

Lecture 1: The Future of Digital Rock Physics (DRP)

Geophysics, reservoir simulation, and logs deal with macro-scale properties. But the physics and associated chemistry of fluid flow, seismic waves, and electrical flow are controlled by pore and sub pore scales architectures and complexity. So is Digenesis – the processes that transform sediments into rocks.

The challenge is to **rigorously** link pore scale to logs, seismic, and reservoir simulation scale. Traditional rock physics – empirical data (sparse) or idealized models (generally not realistic) - has tried to do it but reached its limits. It is the emerging **Digital Rock Physics (DRP)** technology and methodology that can now begin do this.

Specifically, DRP can enable the fast creation of massive rock property databases that can provide for example the multidimensional interrelations between V – perm – NMR – Kr – Pc etc. DRP is also gradually replacing idealized rock physics theory and models of pore shapes, flow, and deformation with rigorous physics while honoring the actual complexity of rock's pore spaces and it enables simulation of reactive fluids' roles in transport, diffusion, dissolution, precipitation, and hence digenesis. Finally, it provides fascinating possibilities for property up scaling from pore to cores to log to seismic and reservoir simulation.

Lecture 2: Rock Properties while Monitoring Non-Equilibrium Rock-Fluid Interactions

We investigate the changes induced in the microstructure of rocks by the injection of reactive CO2 rich water affect pore and bulk rock geophysical properties in carbonate rocks. Our experiments include time-lapse acoustic and transport measurements, along with scanning electron microscopy (SEM) and CT-scan images to track and understand changes in different properties of the pore space e.g., induced porosity *reduction* due to chemo-mechanical compaction resulting from dissolution under pressure. In contrast, porosity *enhancement* due to dissolution. Results indicate that dissolution occurs primarily in the grain-coating cement and the micro porosity of the micritic phase leading to the formation of crack like pores around larger grains, causing both *velocity reductions* and an *increased sensitivity of velocity to pressure*. Dissolution-induced compaction causes also permeability changes during injection.

We then simulate the change using a new computational method that is fast and accurate even when modelling changes in the most complex pore systems.

These reactive fluids effects must be included in future applications and interpretation of 4D seismic, beyond the strict mechanical effects of pore pressure, stress changes, and pore fluid viscosity and compressibility.

Lecture 3: Material and Stress Rotations: The Key to Reconciling Crustal Faulting Complexity with Rock Mechanics

A perennial problem in fault mechanics is that the fault geometries *in situ*—especially of strike-slip faults—often contradict theoretical predictions. According to experimental and theoretical rock mechanics as captured by Coulomb's law, fault directions and motions should correspond simply to stresses in the crust. However, the complex geometrical distribution and regional trends of observable faults in the crust often seem at odds with the regional state of stress. Fortunately, these discrepancies can be neatly reconciled with Coulomb's law if we recognize that many faults did not form in their current orientations, but have rotated over time, and/or the stress field has rotated as well.

I describe a comprehensive tectonic model for the strike-slip fault geometry, seismicity, material rotation, and stress rotation, in which new, optimally oriented faults can form when older ones have rotated about a vertical axis out of favorable orientations. The model was successfully tested in the Mojave region using stress rotation and three independent data sets: the alignment of epicenters and fault plane solutions from the six largest central Mojave earthquakes since 1947, material rotations inferred from paleomagnetic declination anomalies, and rotated dike strands of the Independence dike swarm.

The success of the rotation model in the Mojave has applications well beyond this special region alone. The implication for crustal deformation in general is that rotations—of material (faults and the blocks between them) and of stress—provide the key link between the geology of faults and the mechanical theory of faulting. Excluding rotations from the kinematical and mechanical analysis of crustal deformation makes it impossible to explain the complexity of what geologists see in faults, or what seismicity shows us about active faults. However, when we allow for rotation of material and stress, Coulomb's law becomes consistent with the complexity of faults and faulting observed *in situ*.

Lecture 4: What's driving what?

What's driving what: An active asthenosphere driving a passive lithosphere, or the other way around? Important clues are obtained from looking at the origin and movement of oceanic plateaus and their transformation into accreted terranes, their impact on arc volcanism, the opening of back arc basins, etc. By and large these processes tend to be more consistent with the notion that plate mechanics and the mechanics of plate interactions control what we call plate tectonics, not asthenospheric processes.

This is supported by (a) At convergent plate boundaries - the way oceanic plateaus influence processes when they dock at plate boundaries (e.g., volcanism, mountain buildings); (b) At divergent plate boundaries - the general migration of ridges relative to the asthenosphere suggest that associated so called "hot spots" must also be moving relative to the asthenosphere; (c) Back arc basins - the extensional episodic opening of back arc basins within compressional/convergent settings suggest that it is the strength and cohesiveness of the plate that control this divergent process. The asthenosphere is responding passively; and (d) At transform boundaries - big bends, and bending of major plate boundary faults systems (e.g., San Andreas at the transverse ranges, Dead Sea transform at the Lebanon Mountains) suggest that it is their weakness that controls the behavior of the boundary, not the underlying asthenosphere.