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geoLOGIC NEWS

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Training is NOT Discretionary

A message from our President

Despite the occasional spikes of optimism, the ever-receding price recovery has forced the oil and gas industry to remain cost-conscious by seeking additional, operational cost-efficiencies and continuing to reduce "discretionary" expenses. As we at SCA meet with managers from many companies, a consistent message is that, despite the hiatus in staff technical training over the past two years, budgets will remain tight going into 2018.

Other consistent messages:

1. Reduced training has resulted in dismantling of structured skills management programs;
2. Companies have turned to internal resources to provide training and mentoring, but these late career experts are increasingly rare due to voluntary and involuntary retirements;
3. The "optics" of sending staff to training during a downturn are bad;
4. Managers are reluctant to allow staff to be out of the office for training;
5. Training must be short, just-in-time, tailored to individual company needs, and offered locally to reduce costs;
6. Training should be offered online or be computer-based so it can be self-paced and not necessarily during office hours.

Cost discipline implies improved productivity or "bang for the buck". Training is a relatively small, value-multiplying investment in the ability of technical staff to develop skills, stay on top of current technology, become more efficient in the use of interpretive tools, enhance processes and work flows, and make fewer costly mistakes.

"The only thing worse than training your employees and having them leave is not training them and having them stay." - Henry Ford

Hal Miller
President

in this issue:

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Why You Can't Ignore (or Shortcut) the Geomechanics

by Amy D. Fox, Ph.D.

Over the course of my career, I've seen a massive change in the application of petroleum geomechanics. As with all change, much of it has been good, but some of it hasn't. In my opinion, the difference can be attributed to one very important factor – education. As hydraulic fracturing, which by its very nature is a geomechanical process, took off in the early 2000's, there simply weren't enough people in the petroleum industry with a geomechanics specialization to keep the practice grounded in realistic geology and physics. To this day, I see experienced hydraulic fracturing specialists who don't realize that you can't always compute minimum stress from a log, that the maximum horizontal stress may be important, or that "brittleness" is not the only factor in the success of a frac stage. It's not really anyone's fault; as the saying goes, you don't know what you don't know.

Figure 1 is a flow chart that represents my attempt to tie together various elements of practical geomechanics in the oil and gas industry. Blue represents analyses or interpretations that feed into a geomechanical model. The core of the geomechanical model (orange) consists of knowing the three principal stress orientations and magnitudes. All of the applications (green) rely on this knowledge if they are to be considered complete. Far too often, however, I see operators go directly from, e.g., a minifrac to a hydraulic fracture model, ignoring or only partially considering the full state of in situ stress. Then they are surprised when the frac job doesn't go as planned.

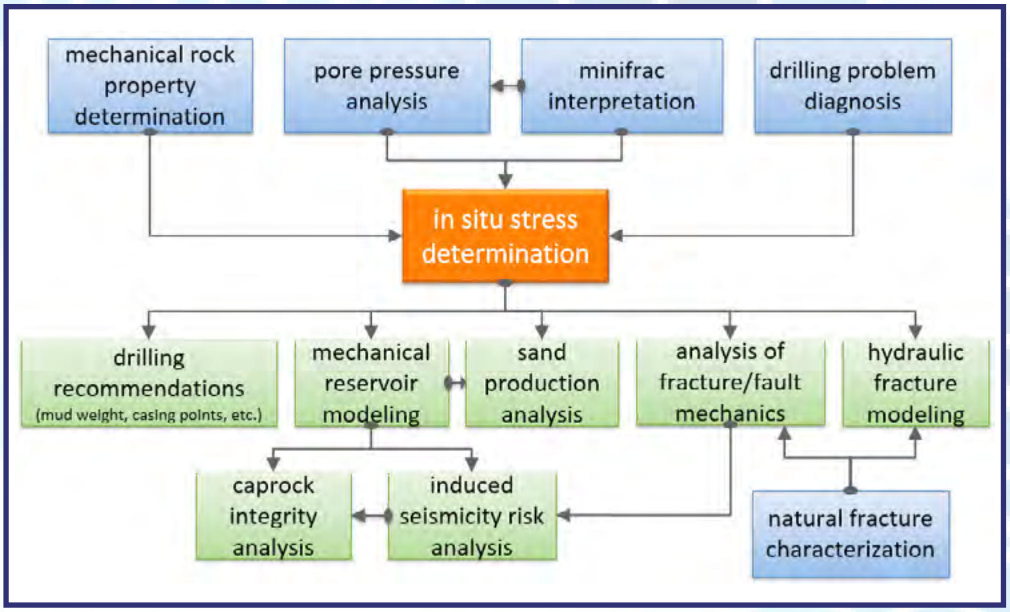
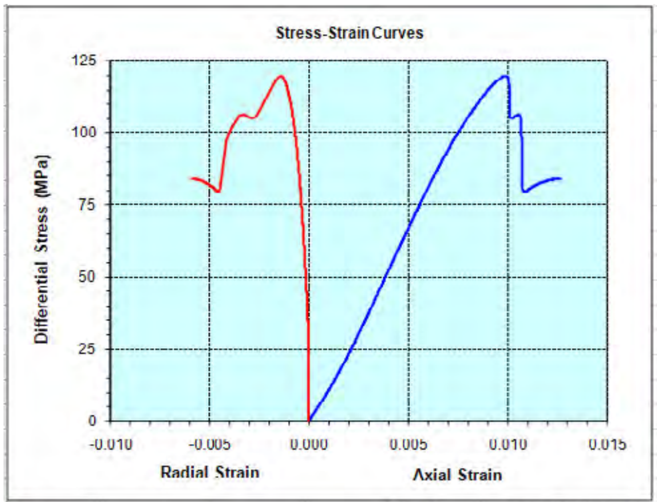


Figure 1. Generalized Geomechanics Workflow and Applications

My course for SCA (Reservoir Scale Geomechanics) includes a great deal of content on how to determine stress, what kinds of data are needed, etc. In this article, I'd like to focus on some of the fundamental geomechanical myths and misconceptions that tend to surprise non-specialists, because that's how one can begin to see the value in the discipline.

Myth #1: Young's Modulus and Poisson's Ratio Are All I Need

There was about a year or two in Calgary, where I'm based, when nobody could stop talking about Young's Modulus, Poisson's ratio and "brittleness." It was almost universally believed that high "brittleness" nearly guaranteed a better rock for hydraulic fracturing. This frustrated me (and continues to frustrate me, as well as many of my colleagues) for several reasons. In most cases Poisson's ratio and Young's modulus are calculated from densities and velocities, either from seismic data or logs, so any variation in them is actually due to variations in densities and velocities. Much work has been done in understanding how a variety of rock properties affect these measurements. Rarely are true triaxial tests performed to measure Young's modulus and Poisson's ratio on core (Figure 2). In short, you can't boil everything down to a simple cross-plot, point to a corner of it, and think that's the whole story. There are many, many factors involved in fracture initiation and propagation. Should we throw "brittleness" out the window? Of course not, but we should use it as just a small part of a larger geomechanical story instead of looking to it as an Easy Button.



Company		Project	Rock Mechanics Study
Sample No.	SP9(2-15)	Depth (m)	1004.21
Confining Pressure (MPa)	9.65	Bulk Density (g/cc)	2.49
Compressive Strength (MPa)	129.50	Young's Modulus (MPa)	14763
Saturation State	As Is	Poisson's Ratio	0.12

Figure 2. Example of a Rock Mechanics Test on Core

> *"Geomechanics provides value by reducing risk, uncertainty and cost, and by increasing the probability of successful production.*
>
> *One positive aspect of the recent industry downturn may be that things slow down enough for geomechanics to catch up and become the critical, pro-active approach to improving our work that it deserves to be."*

Myth #2: A Geomechanics Study is Too Expensive

Throughout my entire career, I've been making the same ineffective argument (yes, I do know the definition of insanity) that the cost of doing a geomechanics study before drilling a well is entirely paid for if it saves about half a day to a day of non-productive time. More than likely, it's going to save a lot more than that. Operators rarely quantify the time and associated cost directly tied to geomechanical problems, but in a recent wellbore stability study I worked on, the client estimated that lost circulation alone cost them more than $620,000. In recent years I have also tried the argument that a geomechanics study costs a mere fraction of a single hydraulic fracture stage, but I'm still met with either blank stares or "we don't have the budget". It is baffling that geomechanics is not part of routine due diligence in an exploration and development program right there along with geology and geophysics. Let me back that statement up with some important facts:

- Geomechanics is how the safe mud weight window for drilling is determined. It is not sufficient to say mud weight should be somewhere between pore pressure and minimum stress. There is a stress concentration at the wellbore wall (and a little bit into the formation) that dictates what the mud weight window is. The stress concentration can only be calculated if the in situ stresses are known. Staying in the safe mud weight window will prevent excessive wellbore failure that leads to expensive problems such as tight spots, stuck pipe and lost circulation. [As a bit of an aside, another misconception that is not necessarily common but does sometimes persist is that the mud weight window is the same for a deviated or horizontal well as it is for a vertical in the same area. In reality, the stress concentration changes as the well is deviated, and it depends on the orientation of the well relative to the in situ stress orientations[1].]

- As mentioned earlier, hydraulic fracture models are incomplete without including the entire geomechanical picture. In addition, in many cases frac stages shouldn't be staged geometrically - they should be staged geomechanically, taking into account how mechanical rock properties and/or in situ stress conditions vary along the well either naturally or because of previous stages or nearby wells. This could lead to substantial cost savings and optimized production.

- Geomechanics will explain how the reservoir will change during production, through either a pressure increase (e.g. waterflood, steam-assisted gravity drainage) or a pressure decrease (depletion). It can explain how those reservoir changes should result in a change in drilling, completions or production strategy, and it can determine the risk of effects such as sand production, subsidence or induced seismicity[2].

An additional problem on this front is that many of the data types needed for a geomechanics study are considered "extra" and cost too much money. Acquiring geomechanical data should be considered an investment, just like seismic (which costs a whole lot more), rather than an extra cost.

Myth #3: Natural Fractures Must be Open to be Permeable

Anyone who has seen an image log analyzed for natural fractures has probably seen the categories “Open” and “Healed” or “Partially-Healed” applied to the picked features (Figure 3). If you are producing from a naturally fractured reservoir, you probably want to focus on intersecting as many open fractures as possible, right? Not really. If you are producing from a naturally fractured reservoir, then you want to find permeable fractures, and permeable is not the same as open. By true definition, an open fracture is a mode-I (opening mode) fracture. In an image log, open fractures are those that don’t show evidence of being healed and are thus potentially “open” for fluid to flow through them. Fractures other than opening-mode can be permeable. The term critically stressed fractures was coined in the 1990’s[3] and refers to fractures on which the shear stress is sufficient to overcome the frictional strength of the fracture surface. These fractures maintain permeability over time through periodic small displacements and the development of rugose surfaces and gouge. They occur at a range of orientations that is related to in situ stress but depends on the magnitudes of the stresses, the formation pressure and the frictional strength of the fracture surfaces.

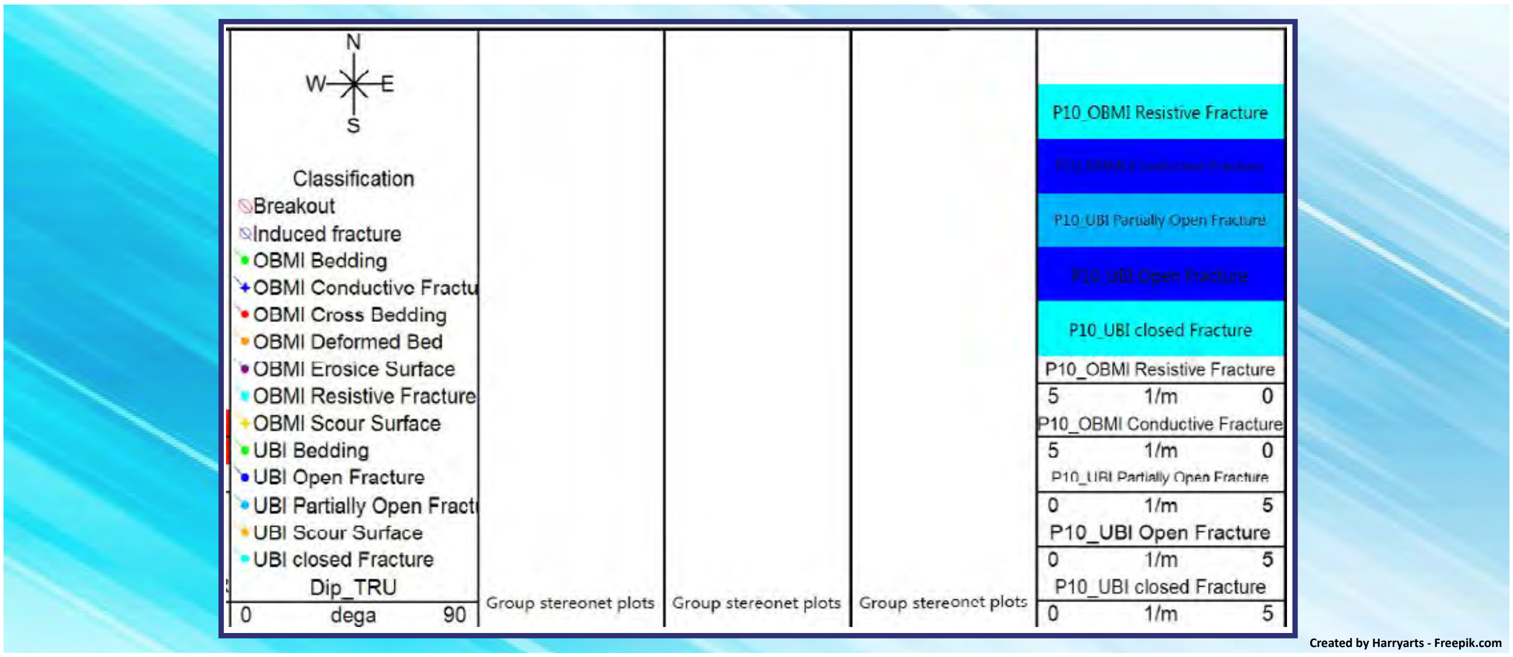


Figure 3. Schlumberger Interpreted Image Log Head with Fracture Classifications

Myth #4: If We Know the Structure, Then We Know the Stress

Structural geologists often look at me askance when I say this, but I don’t much care about geologic structures when I’m determining the present-day stress field. The key is that descriptor, “present-day.” In some parts of the world, structures do represent present-day stress, but in many oil and gas producing areas of the world, they don’t. It is important to separate the structural history of an area from what modern tectonic forces are creating in terms of stress right now.

Myth #5: The Fast Direction is the Maximum Stress Direction

A relatively recent development in logging is the azimuthal shear sonic log. This log measures shear velocity at many azimuths and can indicate the “fastest” orientation, which is often interpreted as the maximum stress direction. Such an interpretation can lead to wildly varying stress orientations along a well (see Figure 4 – maximum stress orientation in this area is known from wellbore failure to be 40-60º), which is not something we usually expect to see. The issue is that there are several additional factors besides in situ stress that might influence shear wave propagation including rock fabric and natural fractures[4].

Myth #6: Our Petrophysicist/Geophysicist Can Do Geomechanics

Maybe he or she can, but in my experience I have seen lots of cases of do-it-yourself geomechanics gone very wrong. Usually an individual takes one course or reads a couple of papers in the technical literature and then feels confident they can apply that awareness-level training on the job without any issues. The trouble is that awareness-level training, in any discipline, is just what it says - it provides awareness only. Further training, supervised experience or mentoring

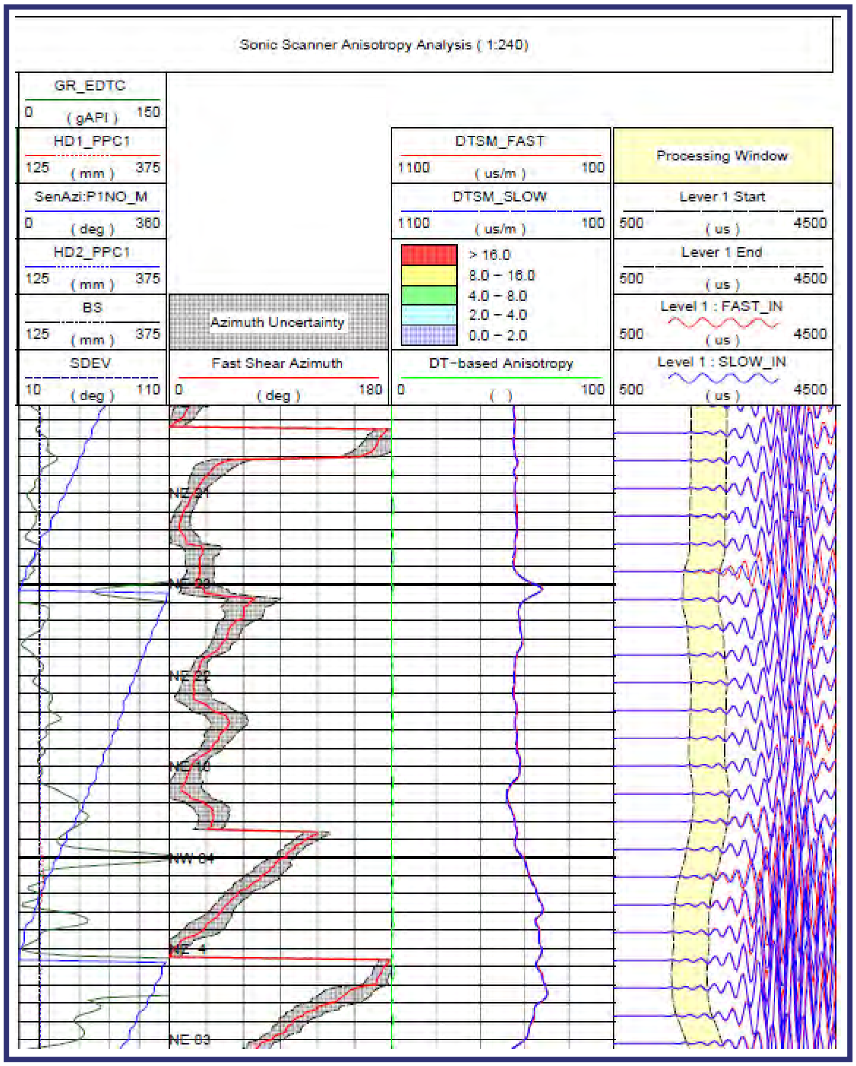


Figure 4. Example of a Schlumberger Sonic Scanner Log

is required before one can be considered skilled at something. When one isn't skilled, one is more prone to make mistakes. A useful example here might be the previously mentioned calculation of stress from logs. Indeed there are long-used methodologies to do this, but they were developed for specific geologic settings. That last part got lost somewhere in history, and I routinely see stresses being calculated from logs, without any attempt at even calibrating those logs to other data, in completely inappropriate geologic settings.

Parting Remarks

Geomechanics provides value by reducing risk, uncertainty and cost, and by increasing the probability of successful production. The relatively sudden need to understand unconventional plays has left the small (but growing) geomechanics community scrambling to keep up and to educate our geologist, geophysicist and engineer peers on when, why and how they should apply geomechanics. Commonly (and unfortunately) geomechanics only becomes involved when something has gone wrong – a well had to be sidetracked twice, a frac stage didn't make sense, an earthquake was felt, etc. One positive aspect of the recent industry downturn may be that things slow down enough for geomechanics to catch up and become the critical, pro-active approach to improving our work that it deserves to be.

Featured Instructor

Amy D. Fox, Ph.D.

Amy earned an undergraduate degree in Geology from the University of New Hampshire and a Masters and PhD in Geophysics from Stanford University. She started her consulting career in 1998 with GeoMechanics International (GMI) in Palo Alto, California. Between 2004 and 2007, she earned her doctorate, completing a thesis entitled "Characterization and Modeling of In Situ Stress Heterogeneity".

Immediately afterwards, GMI asked her to create a training program and career progression for their technical staff of 50+ people globally. Baker Hughes bought GMI in 2008, and in 2009 Amy moved into a corporate training and development role. In 2011, she returned to operations and moved to Canada.

Dr. Fox has authored and co-authored several articles for industry publications and enjoys giving lectures at luncheons and conferences. Extremely dedicated to the geomechanics field, her every effort is an attempt to promote the understanding and application of the geomechanics discipline.

Amy teaches Reservoir Scale Geomechanics, a two-day course focused on:

- Conveying an understanding of why an accurate geo-mechanical model is necessary
- How an accurate model can inform decisions made by various stakeholders within an oil and gas organization

A wide range of data types and analyses are discussed and prioritized. Class time is split between lectures, examples, and hands-on exercises.

This course is being offered July 26-27, 2018.
Click the date to register your seat today!

ARTICLE REFERENCES

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Basics for Making Money

by Bob Shoup, SCA Chief Geologist

The number 1 rule for making money is to spend less than you earn.

Spending Less Money
At this stage of the price-cycle, you have probably cut everything from the budget you can afford to, so spending less is no longer a viable option.

Making More Money
Assuming the price of oil does not increase in the short-term, the way to make more money is to maximize the efficiency of your exploration and exploitation endeavors. That requires you (or your team) to fully understand the trap and reservoir and to leverage that understanding to maximize the amount of hydrocarbons you get out of the ground and minimize the investment needed to do so.

Understanding the Trap
We rely on structure maps to define the trap. If the map is wrong, then your estimate of the reserves is wrong, or worse, you drill a dry hole. Even a small error in the maps can lead to large errors in your decision. If the volume estimate for a 20 million barrel field is off by 10%, you have made a $100,000,000 error (at $50/bbl).

Are you willing to let your workstations have the final say in the structure map? Many companies do! Yet the structure map that comes out of the workstation is almost always wrong, often seriously wrong. We at SCA have seen many dry holes drilled on structure maps that were geologically incorrect, and often geometrically impossible, even when the structure was mapped with 3D data (See SCA's 10 Habits).

We have had many managers tell us that they know the maps are wrong and they deal with the errors by increasing the trap risk. This is simple to do, and may even feel like a solution. But bad maps are bad maps! They will give you erroneous volumes or dry holes. The only solution is to fix the bad maps coming out of the workstation.

So how do you fix bad maps? To do that, you must first understand the basics of making maps and master the fundamentals of geological interpretation and of contouring. There is no better class in the world for teaching the fundamentals of geological mapping than SCA's signature class, "Applied Subsurface Geological Mapping". This class, more than any other industry class, is a course on dry-hole avoidance.

The second step in avoiding bad maps is to conduct a self-audit or technical review of the interpretation and maps once they have been generated by the workstation. A self-audit has seven steps:

1: Make sure the data was loaded and used properly
2: Make sure the contours honor the data
3: Ensure that the contours exhibit contour compatibility
4: Ensure that the contours honor the vertical separation as the cross faults
5: Confirm that the fault traces are properly positioned
6: Review the maps and select seismic profiles to make sure they show the same thing
7: Make sure your maps honor the geology

The process and techniques needed to conduct a dry-hole avoiding audit of your maps and interpretations can be learned in SCA's class, "QC Techniques for Reviewing Prospects and Acquisitions".

Understanding the Reservoir
Once we understand the trap, we need to understand the reservoir. More to the point, we need to understand the distribution of the higher-quality reservoir facies across the trap. The two factors that most control the distribution of porosity and permeability in a reservoir are the depositional setting and its diagenetic history.

“BASICS FOR MAKING MONEY” CONTINUED FROM P6

For carbonate reservoirs, the diagenetic history of the reservoir is generally the principal control on the distribution of porosity and permeability. This makes prediction of the distribution of the best reservoir somewhat challenging as the impact of diagenesis on reservoir quality can vary across a field.

For clastic reservoirs, the depositional system is generally the fundamental control on the distribution of porosity and permeability. Fortunately, the distribution of the higher-quality reservoir facies is very predictable in clastic depositional systems. The processes associated with sediment delivery and sediment dispersal is the fundamental control on the architectural geometry of a depositional system. Furthermore, the distribution of porosity and permeability within the geometries are also predictable.

> *“The way to make more money is to maximize the efficiency of your exploration and exploitation endeavors. That requires you to fully understand the trap and reservoir and to leverage that understanding to maximize the amount of hydrocarbons you get out of the ground and minimize the investment needed to do so.”*

Shales are clastics. The distribution of TOC and silt distribution within the shale is generally predictable at the regional scale by examining the depositional systems that were present along the basin margins. To best understand that, you need to make paleo-depositional environment maps.

The architecture and distribution of reservoir facies in clastic depositional systems as well as the methodology for making paleo-depositional environment maps is covered in SCA's class, “Mapping and Interpreting Clastic Reservoirs”.

Putting Them Together to Make Money

Now that you have a good, and valid, structure map, and a sound understanding of the likely distribution of porosity and permeability, it is time to integrate the two and examine where the hydrocarbons will preferentially flow.

This can be achieved in a dynamic computer model if the model incorporates your understanding of the porosity and permeability distribution as opposed to a stochastically modeled distribution of porosity and permeability.

It can also be handled by thinking. Hydrocarbons will flow up-structure along pathways of higher porosity and permeability. You can use your understanding of the structure to identify potential structural compartments and your understanding of the reservoir to identify any potential stratigraphic baffles. That knowledge can help you optimally design your exploration and development program to maximize the amount of hydrocarbons you produce and minimize the number of wells you need to produce it. And these are the basics for making money!

Upcoming Training Courses

2018

NOVEMBER		
11/13-16	Integrated DW Depositional and Petroleum Systems	Prather
11/13-16	Characterization of Naturally Fractured Conventional and Unconventional Reservoirs NEW	Lorenz/Cooper
11/27-12/01	Applied Subsurface Geological Mapping (Anchorage)	Agah

DECEMBER		
12/04-08	Applied Subsurface Geological Mapping (Kuala Lumpur)	Shoup
12/04-08	Applied Subsurface Geological Mapping	Agah

JANUARY		
01/08-09	PRMS and SEC Reserves and Resources Regulations NEW	Lee
01/10-11	Production Forecasting for Low Permeability Reservoirs NEW	Lee
01/15-17	Shale Reservoir Core Workshop NEW	Hammes
01/22-26	Applied Subsurface Geological Mapping	Agah
01/29-02/02	Pressure Transient Test Design and Interpretation	Economides

FEBRUARY		
02/06-07	Reservoir Management of Unconventional Reservoirs: from Inception to Maturity NEW	Kabir
02/19-20	Integrating Petrophysics with Rock Properties and Production Data to Predict Organic Shale Well Performance NEW	Barba
02/26-05/18	The Daniel J. Tearpock Geoscience Certification Program (Geoscience Boot Camp)	SCA Staff
02/26	Basics of the Petroleum Industry	Howes
02/26-03/01	Project Management Professional Exam Prep	Almaguer

All courses are located in Houston unless noted otherwise.

SCA textbooks - taught and sold worldwide

Applied Subsurface Geological Mapping and *Quick Look Techniques for Prospect Evaluation* are foundation works for accepted practice in O&G exploration and development.

Reserve your seat today! For our full course listing, visit: www.scacompanies.com

About SCA

Our Services

Subsurface Consultants & Associates, LLC provides upstream consultancy and training to professionals in the oil and gas industry. Founded in 1988 by Daniel J. Tearpock, SCA's primary services are consulting and direct-hire recruiting, training services, upstream projects and studies, quality assurance, and oil and gas advisory.

Excellence That Runs Deep

SCA is considered an industry leader in subsurface exploration and development interpretation and mapping. We provide the personnel, technology, and proven methodologies that foster success by enabling better business decisions.

IACET Authorized Provider

We have been accredited as an Authorized Provider by the International Association for Continuing Education and Training, which authorizes SCA to offer CEUs for its programs that qualify under the ANSI/IACET Standard. Professionals who are required to maintain their state, federal or society licensing, registration or certification can fulfill their requirements by attending SCA training courses.

The People & Activities of SCA

Career Advice

Susan Howes, SCA's VP of Engineering (pictured left, center), gave a presentation entitled *Resume Building and Career Planning* to the SPE chapter of Prairie View A&M University. Her talk included a discussion of the "elevator speech", career fair presentation, resume best practices, behavioral based interview questions, interview protocols, and social media tips.

10 Habits Talk

Following the AAPG Geosciences Technology Workshop in Bandung, Indonesia, Bob Shoup (pictured left, center) delivered *The 10 Habits of Highly Successful Oil Finders* presentation to the AAPG Student Chapter at the Institute of Technology. Bob serves as Region Delegate and is a past-chair of the AAPG House of Delegates. He was one of the keynote speakers at the GTW.