1st Edition
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geoLOGIC NEWS

this issue

A Message from our President, Hal F. Miller:

Did We Get it Right this Time?

Anyone who works in or follows the oil and gas industry knows that our business is cyclical and high price environments do not last indefinitely. Despite the surprisingly precipitous price drop over the past several months, those of us who have been around for a few decades recognize the symptoms that accompany a price slump: restricted budgets, falling rig counts and staff reductions for example. This will come as a rude shock to those who have only recently joined the industry, but it is in fact commonplace in our business.

Remember the bumper sticker asking for one more boom and promising we will get it right this time? I think we can argue that the industry did not squander the past five years of strong prices. The vast improvements in expensive drilling and completion technologies that have opened the unconventional reservoir opportunities and deepwater environments around the world would not have happened, or at least not progressed as quickly, if 2009 prices had prevailed over the intervening years. Now the resulting dramatic increases in supply, even in the face of many potentially destabilizing geopolitical risks, are impacting the price to the detriment of the industry but to the benefit of the world's many struggling economies.

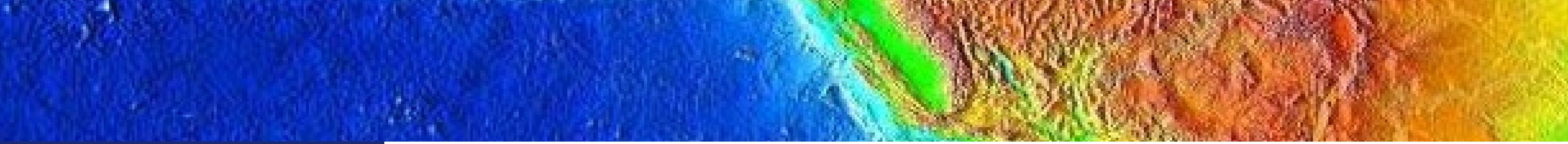
As we have seen before, the dropping price environment began while the lagging cost cycle for oilfield services was still on the upswing. High demand for rigs and services results in equipment and manpower shortages, rising costs, and inevitably project delays and cost overruns. There is no countering the law of supply and demand, and there are voices in the industry suggesting that this correction is not just inevitable but necessary to bring costs back into line.

From the people perspective, the industry has been a significantly positive factor in offsetting unemployment in the US and around the world. Interestingly, the expansion of the industry was not the only driver this time, with the looming demographic factor known as the "Great Crew Change" forcing the industry to bring in new talent before the vast reservoir of knowledge residing in the "Baby Boomer" generation retires. Fifteen years ago it was primarily the majors, large independents and large service providers doing most of the hiring on campus. Today the hiring, driven by the Crew Change, spans companies of all sizes. Hopefully the industry will maintain steady hiring practices and continue to support the departments that are turning out high quality recruits.

The consulting business is often the "canary in the coal mine" during industry contractions. Companies release contractors as one of the first steps towards cost reductions. Staff reductions have now followed, adding to the "natural" attrition that occurred during 2014 through retirement of the baby boomers. Some companies are offering enhanced retirement packages to reduce staff from the top of the experience (and cost) ladder. Any acceleration of this drain on experience will be especially painful as the industry desperately needs mentors for the expanded ranks of millennials.

Consulting has in times past experienced a rebound effect when companies reduced staff but needed to backfill the ranks to get the work done without hiring new employees. Highly experienced and recently retired consultants are a great interim solution to making sure projects stay on track, not to mention continued mentoring of new professionals who will be desperately needed when the price inevitably cycles back up again.

Hal F. Miller



Recommended Courses Related to Habit 7

Applied Subsurface Geological Mapping (ASGM)

This is the most demanded subsurface mapping course in the world. From the newly graduated geoscientist or engineer to the seasoned professional, the course provides the applied, hands-on knowledge required to generate sound subsurface maps. Participants of this course will receive the Applied Subsurface Geological Mapping with Structural Methods 2nd Edition textbook (2003) and a lab manual with exercises. This course covers both fundamental and advanced methods of subsurface mapping that have been used by the most proficient exploration and development geoscientists in the industry, as well as an introduction to some of the more recent advances in interpretation.

Feb 23-27, 2015	Pittsburg, PA
Mar 2-6, 2015	Dallas, TX
Mar 23-27, 2015	Tulsa, OK
Mar 30-Apr 2, 2015	Houston, TX
May 4-8, 2015	Houston, TX
Jun 22-26, 2015	Calgary
Jul 13-17, 2015	Houston, TX

see website for full listing

Quality Control for Subsurface Maps (QLT's)

This unique 3-day course addresses the need for managers to obtain a systematic approach for quickly screening interpretations, maps, prospects and potential resources or reserves and identifying fundamental interpretation, mapping and estimating errors. The course begins with a review of examples of interpretation and mapping errors that led to poorly located wells that proved to be uneconomic or dry, as well as inaccurate reserves or resources estimates. The participants are challenged with a series of real exploration and development prospects and maps for their evaluation.

Jun 29 -July 1, 2015	Houston, TX
Dec 7-9, 2015	Houston, TX

For a complete list of the 2014 public course schedule including course descriptions, target audience and dates available, please visit our website at:

www.scacompanies.com

Exploring the Ten Habits: Habit 7 - *Successful Oil Finders Map all Relevant Geological Surfaces.* *by Bob Shoup*

Example One: Look closely at the map shown in Figure 1. The map was constructed with a grid of closely spaced 2D lines. The company has identified a prospect consisting of a 3-way fault closure that is down structure from a producing field to the north and west of the proposed location. Would you approve the well location?

In the example presented in Figure 1, the company drilled the well and it was a dry hole. On further

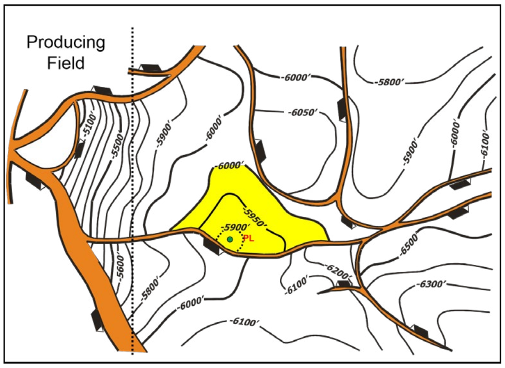


Figure 1: Prospect Map generated from 2D data. The prospect is down structure from a producing field in the adjacent lease to the west. Location and scale omitted for proprietary reasons.

examination, it can be seen that the trapping fault is a screw fault (Figure 2). That is, the fault changes the sense of throw along the strike of the fault. To the west, the sense of throw across the fault is down to the north.

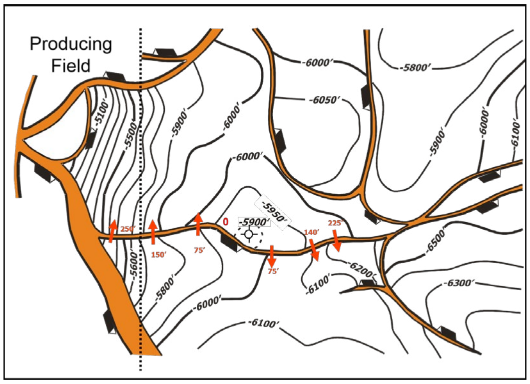


Figure 2: Dry hole drilled on prospect based on a screw fault.

To the east, the sense of throw across the fault is down to the south. We call faults like that screw faults, as the rotate along strike like a screw penetrating the section.

With the exception of strike slip faults and structural inversion where low angle normal faults can be locally reversed by a compressional event, screw faults are geologically and three-dimensionally impossible. Yet screw fault interpretations are so common we have seen them in the user manual for a major interpretive software package. More importantly, drilling traps associated with screw faults has cost our industry hundreds of millions of dollars.

If screw fault interpretations are so common, and so costly, what can we do to avoid drilling them? The answer is easy, make a structure contour map of the fault surface. The vast majority of interpreters pick fault sticks and connect them. Screw fault interpretations occur when interpreters connect two or more separate faults as one. Constructing a structure map of the fault surface will quickly show whether or not the faults have been correctly picked and connected.

Equally important, integrating the fault surface map with the horizon structure map is the only way to ensure that the fault traces are in their proper position for both the hanging wall and footwall blocks. Posting fault polygons places the fault traces in their approximate position. With 3D data sets, the fault polygons should be quite close to the actual position, however, if you are drilling close to one of the two fault traces, is close good enough?

Example Two

Now look at Figure 3. A total of 4 wells have been proposed to develop the field discovered by Well No. 1. Well No. 1 encountered 20 meters of pay in a 50 meter thick (TVT) sand. The trap is an unconformity truncation. Would you approve of this development plan?

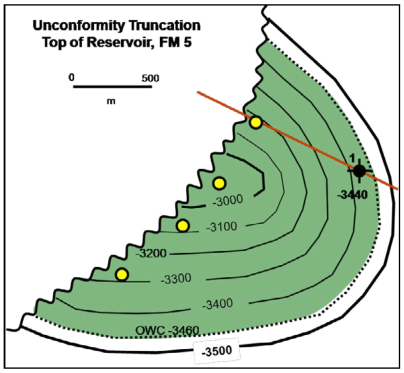


Figure 3: Structure Map for the Top of Formation 5 showing the Proposed Development Plan

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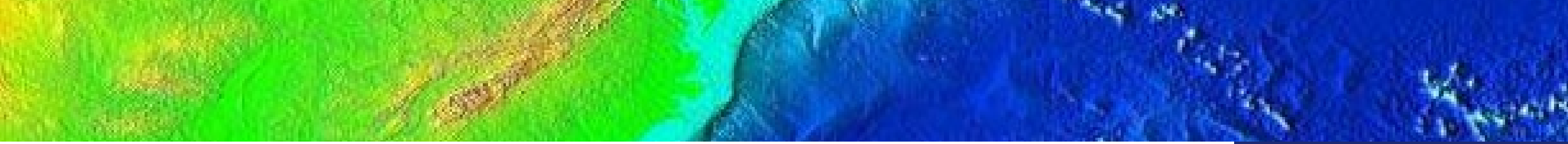


Vorticity in Structural Geology, An Emerging Concept

by: Dr. Lans Taylor

For many earth scientists, structural geology was the dreaded but required part of an undergraduate degree program focused on the description and classification of folds and faults; delivered with a dose of plate tectonics, some rules for constructing cross-sections from geologic maps, and a seemingly endless discourse on stereo-nets. Depending on the teacher, you may have also seen crystal dislocation theory, Mohr-diagrams for stress/strain and failure analysis, earthquake mechanics, kinematic restoration and tectono-stratigraphy, hot spots and mantle plumes, and even models of planetary formation. These subjects range from molecular to planetary scale, from instantaneous to lasting billions of years, from descriptive to predictive, from outcrop to lab to computer modeling. What is the common theme that unites them as structural geology?

If we have a pile of sediment just sitting in a basin, we have geo-mechanics but we don't produce any structure. Geo-mechanics looks at relationships between grain and cement composition, mechanical compaction, pore geometry, permeability, and fluid pressure; microscopic phenomena that result from simple burial of a porous material. In contrast, folds, faults, and other fractures form as a consequence of macroscopic post-depositional movement. Movement is the defining attribute of structural geology. The goal is to characterize relationships between the physical change in rock fabric, the macroscopic motions that caused the change, and the forces that drive the motion.

Displacement is the mathematical description of motion. Consider a mass of rock that is actively moving. We can compare the physical location of any point within the rock mass at two different times. Suppose the point is a grain of sand. The imaginary vector that connects the location of the sand grain at the first time to the location of the same grain at the second time is called the displacement vector. It has a direction and a length. The displacement vector could be drawn to represent instantaneous motion at a specific time, motion of the grain through some window of time, or the cumulative effect of all post-depositional movement. Structural restoration is all about trying to determine the path that points have followed as a rock mass moved.

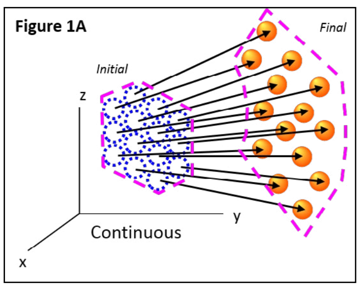


Figure 1A: Displacement fields are generated by comparing the initial and final location of individual particles within a rock mass. The blue circles represent the initial location while the orange spheres are the final position. The black arrows are the individual displacement vectors. The pink outline highlights the shape change that has occurred. Displacement fields can be continuous which produces folding.

That's for a single grain in the rock mass. What if we define a displacement vector for every grain? The collection of displacement vectors fills 3D space and defines a displacement field. It turns out that analysis of displacement fields is a powerful tool for describing how motion is coupled to a physical change in rock fabric. So, let's look more closely at displacement fields.

Staying with the sand analogy, consider the case where every sand grain in a mass of rock moves in the same direction at the same speed: Translation. Alternately, imagine swinging the entire rock mass around some central pivot point: Rotation. Translation and rotation do not produce any change in the spacing or ordering of grains. They are called rigid body transformations. Pick up your mouse, flip it over. At no point in that process did you have to crush your mouse.

Now consider the case where some of the sand grains move in a different direction or a different distance compared to others. If the sand grains diverge from one another but never change their internal order, the volume occupied by the initial mass increases (Fig 1A). Similarly, you could imagine drawing a vector field where individual displacement vectors converge through time decreasing the volume occupied by the initial mass (that would be like crushing your mouse). How do we accommodate volume change in rock? That's geo-mechanics and Mohr-diagrams and failure envelopes, but the easy answer: joints create porosity, pore collapse and pressure-solution destroy porosity. Both are fundamentally volume change process.

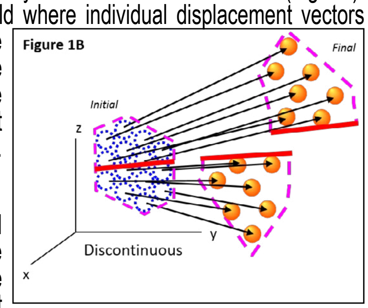


Figure 1B: Displacement fields are generated by comparing the initial and final location of individual particles within a rock mass. The blue circles represent the initial location while the orange spheres are the final position. The black arrows are the individual displacement vectors. The pink outline highlights the shape change that has occurred. Displacement fields can be discontinuous which produces fracturing.

If all of the grains in our deforming sand body remain next to the grains they were deposited with, we call it a continuous displacement field and the result is folding. In contrast, if there is an abrupt discontinuity in the displacement field some grains become juxtaposed against grains they were not originally next to. A fracture is defined as a discontinuity in the displacement field (Fig1B). Fractures include faults where the motion is parallel to the discontinuity surface; and joints, compaction bands, and stylolites where the motion is perpendicular to the discontinuity surface.

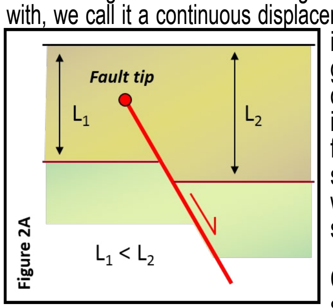


Figure 2A: Analysis of an isolated fault with both tips within the sedimentary section. Cartoon diagram showing changes in strata thickness on either side of a fault tip.

Consider a fault that terminates within the stratigraphic section. In the center of the fault, there is some finite slip magnitude, but as you approach the fault tip, it loses slip decreasing to zero. Conceptually, if you measure the distance between a layer that is offset by the fault and a layer beyond the fault tip that is not offset, there will be a difference in the thickness (Fig 2A) with the up-thrown foot-wall side being shorter than the hanging-wall side.

Featured Instructor:

Lans Taylor, Ph.D.

For the past seventeen years, Dr. W. Lansing Taylor has been an accomplished structural geologist with extensive industry and field experience specializing in Structural Geology, Fractured Reservoirs, Geomechanics and Field Geology. Dr. Taylor joined SCA as an instructor in 2008. His Structural Styles in Petroleum E&P short course and the accompanying Structural & Sequence Stratigraphy Field Course (Hill Country, TX) are consistently rated at the top of the scale among our students. His development and EOR experience includes Hugoton, Golden Trend, Permian Basin, Ozona, and the Austin Chalk, while his exploration experience includes Alaska, North Africa, Middle East, and SE Asia.

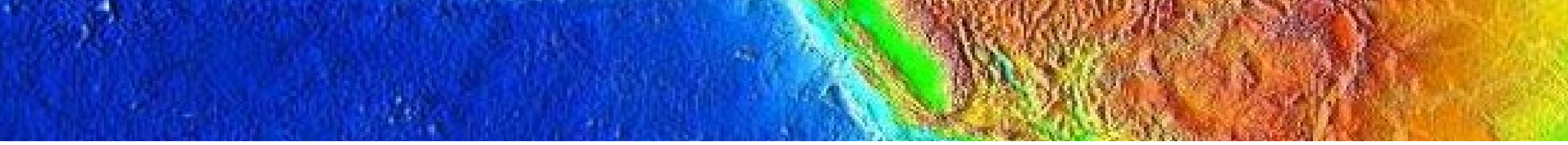
Dr. Taylor is currently working as a Sr. Structural Geologist with Talisman Energy and previously performed both technical and management roles with Anadarko Petroleum. His most recent experience with Talisman includes structural evaluation, providing in-house training, implementing new technology, interfacing with academic research and structural consortia, petroleum system analysis, and risk assessment from basin to wellbore scale. While at Anadarko he worked as a project advisor and fractured reservoir specialist aiding exploration and development teams in solving issues related to structural geology.

His accomplishments include three discovery wells on the Gulf Coast, one in Alaska, and a new basin entry for Anadarko in Indonesia. Following the merger with Kerr McGee, he managed the evaluation of their mid-continent and west Texas fields, and made all G&G presentations for the subsequent divestiture of assets (proceeds ~$2 Billion).

Dr. Taylor received his B.A. in mathematics and geology at Skidmore College, receiving department honors of Suma Cum Laude. He received his Ph.D. in Quantitative Structural Geology, "Fluid flow and chemical alteration in fractured sandstone", Department of Geological and Environment Sciences from Stanford University.

Dr. Taylor teaches these courses for SCA:

- ***Structural Styles in Petroleum Exploration & Production***
- ***Structural and Sequence Stratigraphic Field Course (Hill Country, TX)***



Vorticity in StructuralGeology

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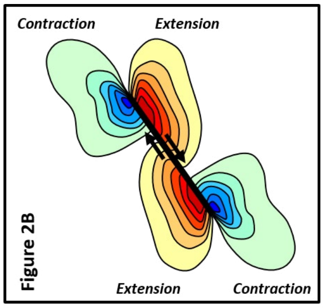


Figure 2B: Analysis of an isolated fault with both tips within the sedimentary section. The change in volume induced by decreasing the slip magnitude from the center of the fault to its tip.

This creates quadrants of relative contraction and relative extension in the rock mass surrounding the fault (Fig 2B). The motion localized on the fault must involve motion of the surrounding rock too, so we find stress concentrations developed at fault tips, fault bends, and rapid changes in fault slip. These are geometric impediments that transfer displacement on the discrete fault surface into deformation of the surrounding rock.

In an applied setting, if we can map a fault in seismic, we can model the local stress concentrations around it based on the geometry of the fault surface. For simple fault geometries, there is an analytical solution (assuming the rock is homogeneous linear elastic and the fault is a friction free elliptical displacement discontinuity). Whether we use the computer, or the analytical solution, or just think about it, we come to the same result (Fig 2C). The displacement field around the fault has areas where the displacement vectors converge. These correspond to the areas of relative contraction. On the opposite side of the fault tip, the displacement vectors diverge and correspond to areas of relative extension.

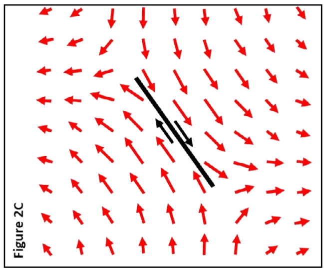


Figure 2C: Analysis of an isolated fault with both tips within the sedimentary section. The particle displacement vectors for an increment of fault movement.

Much like a single 3D vector can be resolved into three components each acting along one of the coordinate directions, we can resolve the displacement field into three partial spatial derivatives called the divergence, gradient, and curl. The divergence measures the extent to which the displacement vectors spread out or converge perpendicular to the direction of motion (Fig 3A), while the gradient measures the change in velocity parallel to the direction of motion (Fig 3B). The curl is a measure of the magnitude of rotation (Fig 3C).

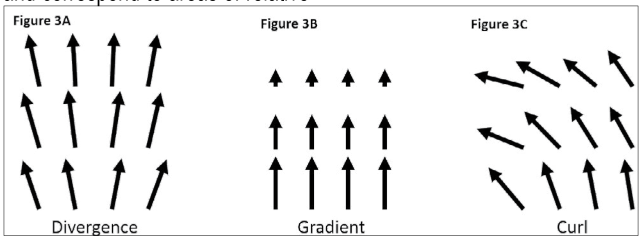


Figure 3 (A/B/C): Analysis of vector fields. 3A: Divergence measures how much the displacement vectors spread out perpendicular to the flow direction. 3B: Analysis of vector fields. Gradient measure change in velocity in the direction of flow. 3C: Analysis of vector fields. Curl is a measure of the rotation of the flow paths. All three parameters can have positive or negative values.

In fluids, rotation often produces vortices. A vortex is simply a closed flow path where material rotates around a central axis. Fluid vortices are complex and beautiful structures present throughout nature at a wide range of scales. The most obvious examples are galaxies, solar systems, hurricanes, and tornados. Vortices come in several flavors. The Taylor-Couette vortex has a stationary point in the center and increasing velocity as you move out from the vortex axis (Fig 3D) while a rotational vortex is essentially a rigid body rotation (Fig 3E) as simple as throwing a spiral touchdown pass with a football. Most turbulence in fluids, such as eddies in a river and storm systems, produce irrotational vortices where the velocity increases as you approach the central axis (Fig 3F).

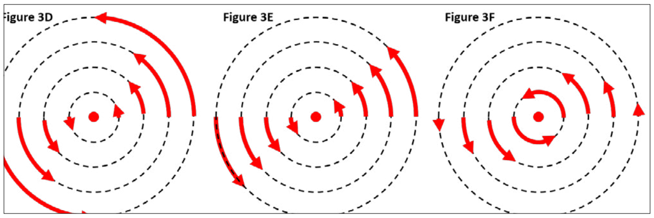


Figure 3 (D/E/F): Analysis of vector fields. 3D: Taylor-Couette vortex with null point in center. 3E: Rotational vortex (rigid body). 3F: Irrotational vortex where the center spins faster than the periphery.

Interlocking gear-like vortices are common in fluids and are pervasive in NASA's most recent compilation of ocean currents, "Perpetual Ocean" (Fig 4). Try drawing three adjacent circles on a page, such as the base of a tetrahedron or the unit cell of hexagonal close pack. If you try to rotate one circle, the other two move in the opposite direction and come into conflict with one another. Vortices come in even numbers, and stack up in cubic close pack.

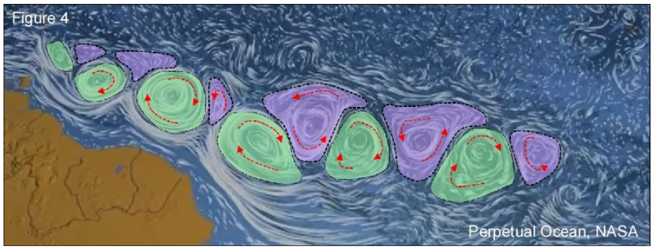


Figure 4: Numerical simulation of ocean currents from NASA showing clear vorticity where the Atlantic equatorial current is deflected northward by the northeast coast of South America.

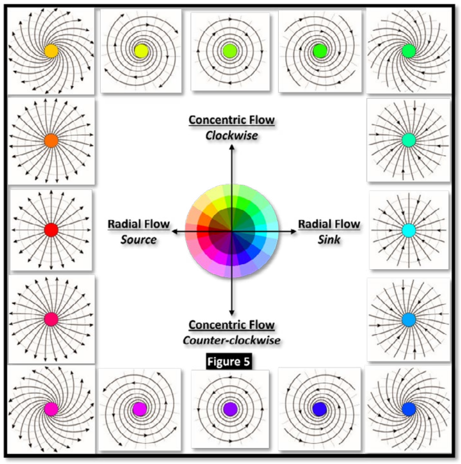


Figure 5: Classification of 2D vortex patterns based on radial and concentric flow. The radial flow can be either a source or sink and the concentric flow can be directed either clockwise or counterclockwise.

In ocean currents, there may be up-welling or down-welling of fluids in the center of the vortex. Viewed on a 2D plane on the sea surface, this is captured in the divergence of the vector field. Since fluids are incompressible, the divergence becomes a local source / sink term. Similarly, the curl can be positive or negative corresponding to clockwise or counter-clockwise rotation. Together, these allow us to establish a simple classification of vortices (Fig 5). This classification does not include a component of linear flow. We can superimpose linear flow on the whole system and the components of the displacement fields just add algebraically.

If we go back and look at the displacement field around a fault tip, we see that it is dominated by rotational displacement. There are four partial vortices (Fig 2D). Adjacent to the fault the dominant motion is counter-clockwise rotation while ahead of the fault tip the rotation is in the opposite direction. Adjacent vortices which share a common boundary rotate in opposite directions. In this example, the four vortices lock together like gears except along the fault. As a discontinuity, the fault does not preserve this relationship.

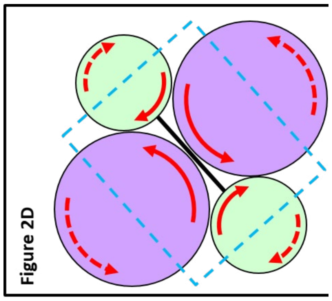
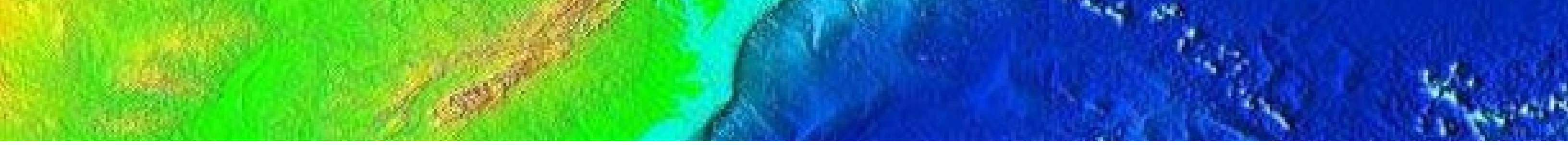


Figure 2D: Analysis of an isolated fault with both tips within the sedimentary section. Interpretation of the rotational component of the displacement field. Note that the rotation here does not form a vortex because it is not a closed loop. Only the areas inside the dashed blue box coincide with the actual displacement field.

In this solid material, these are not true vortices. The outer half of the rotational cell is not present (outside of the dashed blue line in Fig 2D), and the displacement field does not close back on itself. Rather the material is extending horizontally and thinning vertically in the far field. So, these are half vortices that die out and merge with a linear displacement field away



Vorticity in StructuralGeology

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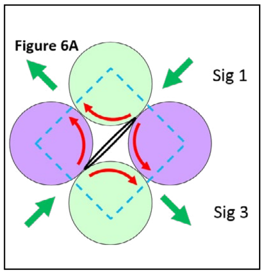


Figure 6A: Analysis of en-echelon joints. The rotational component of the deformation field surrounding an opening mode joint. The joint is the inclined surface running through the center of the four rotational cells. Like the fault example, only part of this pattern is manifest for a single joint outlined by the dashed blue line.

from the fault. Nonetheless, alternating rotation is part of the local displacement field and the concept of interlocking gears may help illuminate some of the patterns formed when multiple faults interact.

Like faults, joints are also displacement discontinuities but the two walls have moved apart perpendicular to the fracture face instead of sliding parallel to it. The dominant character of the displacement field is linear motion away from the joint surface, but there is a second order rotational effect too. As the joint dilates the walls rotate away from the center and the tips move inward. If we isolate and view just the rotational component we find that the joint sits in the middle of four rotational cells (Fig 6A). Unlike faults, there is no contrary motion along any of the vortex boundaries so there is no shear required.

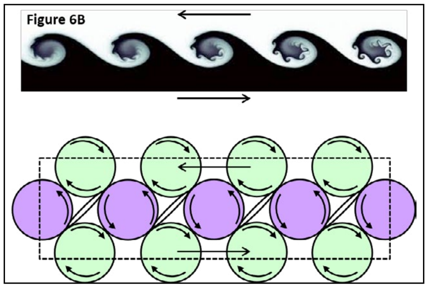


Figure 6B: Analysis of en-echelon joints. Kelvin-Helmholtz instability along a fluid seam and a model of rotation around joints in an en-echelon arrangement. Systems of joints can produce true vorticity while isolated fractures only produce part of the rotational pattern.

Although these rotational patterns do not extend much further than the half length of the joint (suggested by the dashed blue box in Fig 6A) when multiple fractures are in proximity to one another, their associated areas of rotation may overlap. The overlapping areas will still form even-numbered sets of interlocking-gear like vortices.

The resulting geometry of en-echelon fracture systems in many ways resembles the geometry of a characteristic flow pattern called a Kelvin-Helmholtz oscillation (Fig 6B). A Kelvin-Helmholtz oscillation forms when one body of fluid is moving past another. The interface between moving fluids is called a seam. Any small instability along the seam rotates and then amplifies with continued flow until it evolves into a set of rollers, like tube shaped ball bearings that migrate in the direction of flow but at a slower rate. In the space between rollers, fluid is drawn in from both above and below but does not make a closed loop, just an indented perturbation in the flow field. When multiple joints are aligned in an en-echelon configuration, the vorticity between fractures results from overlap of the rotational fields associated with each bounding fracture (Fig 6C). Individual fracture produce open-rotation while systems of fractures can produce true vorticity.

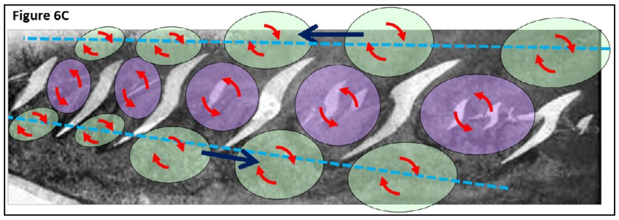


Figure 6C: Analysis of en-echelon joints. An outcrop photo of en-echelon joints interpreted as a Kelvin-Helmholtz oscillation.

At this point, it is not clear if thinking about rotation and the concept of vorticity in solid materials will add to our understanding of rock deformation or if it's just an alternate way of expressing patterns already documented through conventional mechanical analysis. But, we know that vorticity dominates fluid motion and beneath our rigid crust, 97% of our planet is a plastic solid, a visco-elastic material, or truly a liquid. All three of these rheologies are expected to produce characteristic flow patterns including vortex.

We've all heard it, but we just don't intuitively believe it: The crust is paper thin. It seems rigid to us, but at a planetary scale it's weaker than wet bread and easily affected by the dynamics of the fluid-like layers below. It appears that there are at least two different scales where rotational dynamics of the interior of the earth are transmitted up and manifest in patterns of brittle deformation on the surface.

Our planet is vertically stratified by density with a core of solid metal that rotates about one degree per year faster than the crust. One degree per year – that means that during the Cenozoic alone, the core has rotated almost 200,000 times more than the crust, and more than two million times since the Cambrian. This perpetual differential rotation generates frictional heating which is maximum at the equator and minimum at the poles. That equatorial heating causes the liquid outer core to convulse, probably with two giant Taylor-Couette vortices looping the equatorial region extending north and south to at least middle-latitudes if not further. This produces a concentrated flow, probably of charged elemental iron that induces our magnetic field and pumps heat into the lower mantle.

The lower mantle controls global tectonics and the basic distribution of continental and oceanic crust. Applying tomography to natural earthquake seismicity we've been able to image major heterogeneities in the lower mantle. Beneath areas where oceanic crust is subducting there are horizontal sheets of the ancient sea floor stacked one atop another slowly sinking. In other areas there are massive mantle plumes, not to be confused with the relatively tiny hot spots up near the surface. These massive regions of hot low density material in the lower crust rise up with a morphology much like a thunderstorm.

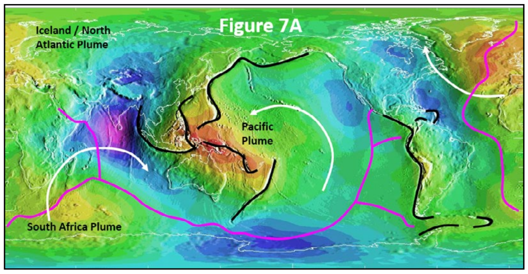


Figure 7A: The shape of Earth and the fundamental motion of plate tectonics. Both phenomenon are controlled by vortices in the lower mantle that involve the same geometry as a Von Kerman vortex street. A simple tectonic map of the world on a contoured map of the geoid.

The force of gravity experienced on the land surface is a result of the average density of everything between the surface and the center of the earth. Mantle plumes are hot and have a lower density than the cold sinking slabs of ocean crust. Consequently, mantle plumes are expressed as the long wavelength signal in the Geoid, the deviation of the surface of our planet from a sphere (Fig 7A).

There are three mantle plumes. They radiate out from the core along the radian of an equilateral triangle. The largest rises at the equator underneath Papua New Guinea and feeds the Pacific spreading center. The Pacific basin sitting above this rotates counter-clockwise, so the underlying plume probably does too. The rotation is not huge, but it's evident in the differential opening rate of the pacific center which increases to the north.

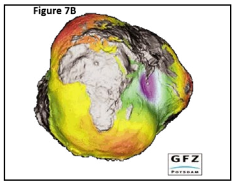
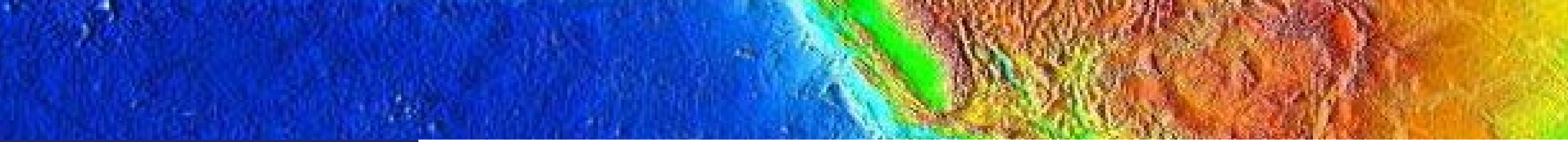


Figure 7B: The shape of Earth and the fundamental motion of plate tectonics. Both phenomenon are controlled by vortices in the lower mantle that involve the same geometry as a Von Kerman vortex street. GFZ Potsdam "Potato Earth" an exaggerated projection of the Geoid showing the gravity expression of the three mantle plumes.

The second plume sits at 60 degrees south beneath the Kerguelen Platform (southeast of the Horn of Africa), feeds the south Atlantic and Indian oceans, and rotates clockwise. The third sits at 60 degrees north underneath Iceland, feeds the north Atlantic and also rotates clockwise. The surface deflection associated with the plumes is nicely illustrated in the now famous "Potato Earth" from GFZ Potsdam (Fig 7B).



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HAPPY ANNIVERSARY

Cathy Jankovic	07/13/11	3yrs
Marcia McKinney	07/23/13	1yr
Matt Nowak	08/07/06	8yrs
Joe Brewton	09/01/91	23yrs
Donna Darilek	08/16/10	4yrs
Hal Miller	08/16/04	10yrs
Jenifer Miller	09/01/14	1yr
Martha Hester	09/15/08	6yrs
Kina Lamb	10/12/07	7yrs
Mark Connor	11/01/10	4yrs
Matthew Miller	11/12/12	2yrs

Vorticity in StructuralGeology

continued from Page 5

The pattern of mantle circulation is dominated by upwelling and radial expansion above the mantle plumes, but there is also a rotational component. The three rotating cells link together in another characteristic form called a Von Karman vortex street. These patterns are often nicely developed in clouds when they blow past large islands (Fig 7C). Once formed, the vortex can persist for a prolonged duration. It seems likely that we've had the same global tectonic environment since at least the Jurassic and the break-up of Pangea.

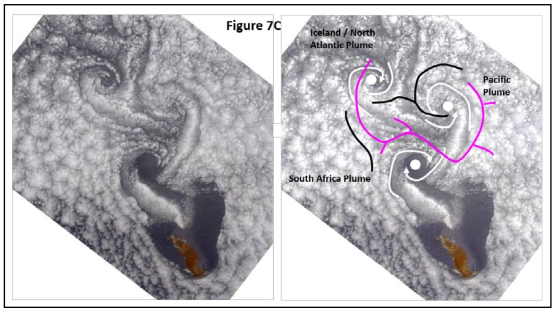

Figure 7C: The shape of Earth and the fundamental motion of plate tectonics. Both phenomenon are controlled by vortices in the lower mantle that involve the same geometry as a Von Kerman vortex street. A Von Kerman vortex street formed in clouds blowing past an ocean island. On the right, the cloud image has the simple tectonic boundaries from the map above so you can identify how the major tectonic boundaries of Earth match the geometry of the Von Karman vortex street.

Within this global pattern, there are at least two regions that display Von Karman vortex streets at a smaller scale. Both are associated with oblique subduction and are possibly a consequence of fluid seams developed in the mantle where viscous drag on the boundary of the Pacific plume induces counter rotation of the Kerguelen and Iceland plumes. One zone runs from the Eastern Syntaxis of the Himalaya to Fuji in the South Pacific (Fig 8), the other from Alaska to the Caribbean (Fig 9).

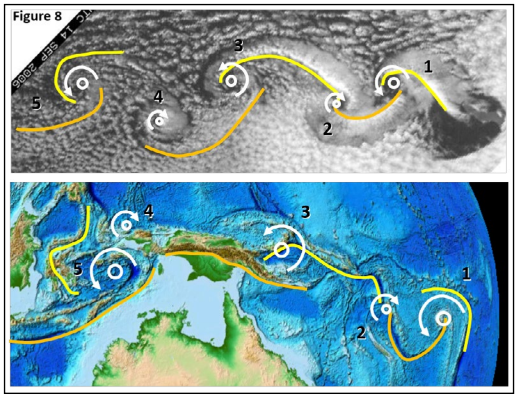

Figure 8: Preliminary interpretation of the Banda-Arc to Fuji as a Von Karman vortex street. Formed on young thin oceanic crust, this is the most obvious and compelling example on Earth. Image of Von Karman vortex street in a cloud provides a geometric analog. If present, these vortex are probably in the asthenosphere at depths greater than 60 km but less than 600 km.

Figure 9

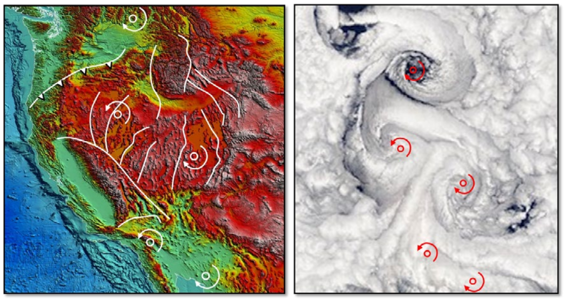

Figure 9: Preliminary interpretation of the Basin and Range Province and a Von Karman vortex street developed in thick cloud cover at the correct scale for geometric comparison. Relatively thin crust due to large amounts of extension facilitates transmission of the pattern from deeper levels into the brittle upper crust. If present, these vortex are probably in the asthenosphere at depths greater than 60 km but less than 600 km.

The scale of rotation evident on these two seams suggest that the underlying vortices rotate at a smaller scale that the mantle plumes, generally around a few hundred kilometers across. This is probably flow confined to the largely liquid asthenosphere.

There are probably other examples. The amalgamated mountain belt including the Pyrenees, Alps, Carpathian, Zagros, Caucus, through Afghanistan to the Western Himalaya Syntaxis have all kinds of interesting and unresolved complexity. They may exhibit Von Karman vortices, but overprinting of multiple phases of deformation complicates the story and makes any avant-garde interpretation tricky to defend.

There are probably other geologic processes where some concept from vorticity has application. In structural geology, any alternating fault process, such as conjugate faulting where motion oscillates between one orientation of faulting and the other may be displaying behavior consistent with a temporally evolving vortex system. Similarly, the alternation between regional and counter-regional growth faults common in the sediment dominated Cenozoic deltas of the world may reflect linked rotational process with a consistent periodicity linked to horizontal axis vorticity in the hanging-wall of large growth faults.

Applications may not be limited to structural geology. It seems possible that hot spots are like upside down tornadoes boring into the bottom of the crust, spurned from somewhere deep in the asthenosphere. In the sedimentology world, it has already been proposed and published that facies distribution of the Eagleford source rock may be controlled by persistent ocean vortex circulating in the Cretaceous Gulf of Mexico. Certainly the edge of turbidity flows can induce Kelvin-Helmholtz oscillations that turn into underwater tornadoes that scour mega-flutes in the sea floor when they touch down, as documented for the Scotia Shelf collapse in the early 1900's and in the Ross Sandstone deep water fan system in Ireland.

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Habit 7 (continued from page 2)

If you approved this plan, you would be leaving behind some of the attic reserve, as this plan would not drain the unconformity wedge (Figures 4 and 5). To properly estimate the recoverable reserves and to optimize the development plan for this discovery, structure maps need to be constructed for the unconformity and the top and base of the reservoir.

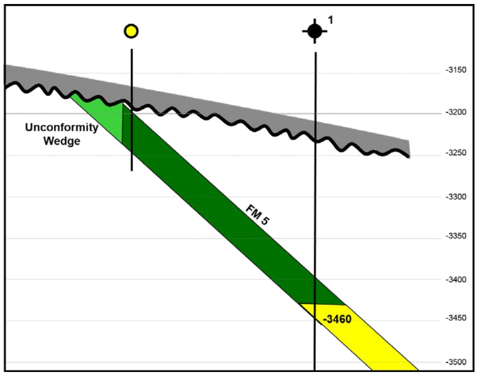

Figure 4: Cross Section for the New Field Discovery showing the Unconformity Wedge

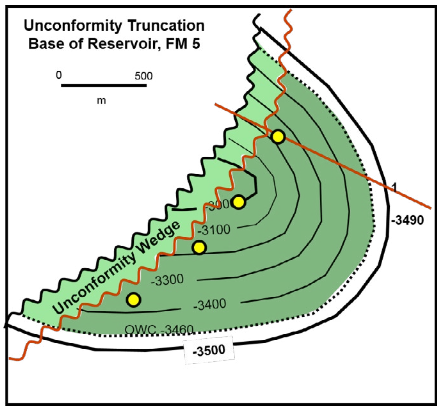

Figure 5: Structure Map for the Base of Formation 5 showing the Area of the Unconformity Wedge

So there you have it, a simple way to ensure accurate reserve estimates and to minimize the risk of drilling dry holes is to map all relevant geological surfaces.

Editor's Note: To learn more about fault surface mapping and other tools, methods, and techniques to help ensure accurate subsurface maps, register for SCA's signature course Applied Subsurface Geologic Mapping(LINK). Visit www.scacompanies.comto learn more about SCA's training Program and other services, or to read more of the 10 Habits of Highly Successful Oil Finders.

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Principles of Mapping on the Workstation

Designed in response to client and participant feedback, ***Principles of Mapping on the Workstation*** is a next generation follow-up to SCA's popular flagship course, *Applied Subsurface Geological Mapping*. (To ensure adequate preparation, it is strongly advised that participants attend Applied Subsurface Geological Mapping prior to attending Principles of Mapping on the Workstation, although it is not a formal pre-requisite.)

COURSE OBJECTIVES:

- Provide a basic understanding of subsurface petroleum geologic methods.
- Apply proper subsurface mapping techniques to making more accurate maps on the workstation.
- Recognize valid geological interpretations and maps.
- Integrating various data into 2D and 3D maps (models).

COURSE THEMES:

- Traditional Lecture - PowerPoint Presentations
- Demonstrations - Digital data will be manipulated by the instructor.
- Exercises - Digital data will be worked by the student.

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Seats Available!

next class:

April 20-24, 2015

For more information about SCA's Prinicples of Mapping on the Work-station, contact:

SCA

Mary Atchison
V.P. of Training Operations
matchison@scacompanies.com
(ph)+1.713.789.2444

2015 Upcoming Training Courses

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- 02/23-27/15 - Applied Subsurface Geological Mapping - Pittsburg, PA

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- 03/02/15 - Basics of the Petroleum Industry - Houston, TX
- 03/02-06/15- Applied Subsurface Geological Mapping - Houston, TX
- 03/03-06/15 - Structural Styles in Petroleum Exploration & Production - Houston, TX
- 03/07-08/15 - Structural & Sequence Stratigraphy Field Course - Hill Country, TX
- 03/09-13/15 - Practical Seismic Exploration & Production - Houston, TX
- 03/16-20/15 - Practical Interpretation of Open Hole Logs - Houston, TX
- 03/23-27/15 - Mapping & Interpreting Clastic Reservoirs - Houston, TX
- 03/23-27/15- Applied Subsurface Geological Mapping - Tulsa, OK

APRIL
- 03/30-04/02/15 - Applied Subsurface Geological Mapping - Houston, TX
- 04/06-10/15 - Cased Hole and Production Log Evaluation - Houston, TX
- 04/06-08/15 - Seismic Interpretation Workshop - Houston, TX
- 04/09-10/15 - Basic Petroleum Engineering for Non-Engineers - Houston, TX
- 04/11 - Modern Coastal Systems of Texas Field Course - Galveston, TX
- 04/20-24/15 - Principles of Mapping on the Workstation - Houston, TX

MAY
- 05/04-08/15 - Applied Subsurface Geological Mapping - Houston, TX

JUNE
- 0601-05/15 - Integration of Rock Logs, Test and Seismic Data - Houston, TX
- 06/08-12/15 - AVO, Inversion and Attributes: Principles and Applications - Houston, TX
- 06/15-16/15 - Fundamentals of Petroleum Geomechnics - Houston, TX
- 06/15-18/15 - Drilling Basics for the Geoscientist - Houston, TX
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- 06/22-26/15 - Applied Sequence Stratigraphy of Clastic Depositional Systems - Houston, TX

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REGISTRATION should be made at least one month prior to the start of a course. Paid registrations will be accepted until the day before the course. Registrants will receive a confirmation e-mail within 48 hours of registration and will receive complete venue information two weeks prior to the first day of class. Registration is confirmed upon receipt of payment.

About SCA

Subsurface Consultants & Associates, LLC provides upstream consultancy and training to stakeholders in the oil and gas industry. Founded in 1988 by Daniel J. Tearpock, SCA's four primary services include geoscience and engineering consulting, upstream projects & studies, training services, and direct hire recruitment.

Industry Events

NAPE	February 11-13, 2015	Houston, TX
APPEX	March 3-5, 2015	London
OTC	May 3-6, 2015	Houston, TX
AAPG	May 31 - June 3, 2015	Denver, CO
EAGE	June 1 - 4, 2015	Madrid, Spain
URTeC	July 20 - 22, 2015	San Antonio, TX
AAPG ICE	September 13-16, 2015	Melbourne, Australia

SCA HAS TRAINED OVER 26, 000 GEOSCIENTISTS AND ENGINEERS AND HAS EVALUATED OVER 5,000 PROSPECTS WORLDWIDE IN OVER 50 COUNTRIES

The People & Activities of SCA

SCA sponsors hole @ Youth Reach Houston

On September 29, 2014 as pictured to the right (l-r): Matthew Miller, Mark Connor, Tim Riepe and Matt Nowak represented SCA's sponsorship of a hole at Golfcrest Country Club for *Youth Reach Houston*. At the end of the evening, $24,000 had been raised for Youth-Reach Houston!

SCA proudly celebrated its 26th Anniversary on December 1, 2014

Pictured (l-r) are SCA's Executive Management Team, Tim Riepe, Hal Miller, Mary Atchison and Matt Nowak. SCA looks forward to sharing another great and successful 27th year in 2015.

UNCONVENTIONAL RESOURCES TECHNOLOGY CONFERENCE FUELED BY SPE • AAPG • SEG
25-27 August 2014 • Denver • Colorado Convention Center

SCA was well represented with several of our staff in attendance at the 2014 Unconventional Resources Technology Conference (URTeC) in Denver, CO, August 25-27, 2014 and the Gulf Coast Association of Geological Societies (GCAGS) in Lafayette, LA, October 5-8, 2014. We met many old and new friends.

Nicole McMorris-Lavergne & Danielle Lavergne, daughters of Dan Tearpock were present to accept a special honor in memoriam for our founder, Daniel J. Tearpock as the recipient of the 2014 GCAGS Transactions Dedication for his contributions to the GCAGS and the advancement of the geosciences.