20211025 – Presentation Jim Granath - Houston Geological Society – Unofficial transcript

Mon, 10/25 11:35AM • 1:30:50

SUMMARY KEYWORDS
inversion, blocks, rift, developed, system, thrust, displacement, cretaceous, relative, structures, basin, fault, inaudible, places, lateral, kilometers, basement, big, field, people

SPEAKERS
Jim Granath, Moderator, Paul, Boris, Ross,

Jim Granath 04:52
I'm taking my company hat off, right, and will speak as a working scientist from here on out. There's going to be very little about Kavango or anything like that. But let's clean up any questions that are lingering.

Jim Granath 05:28
I see one from Ken Li, about other exploration efforts, you know, Ken I know zero about it? I know there's interest in the surrounding blocks and things like that, but I don't even know where PEL 93 is. As far as I knew we were the only ones onshore drilling, because we're the only ones with an onshore drilling rig. But I may be wrong. Of course, there's stuff in Angola that's available, but it doesn't get out of Angola.

Jim Granath 06:02
Can I talk a little bit about the potential source rock? No, I'm sorry, I can't. I've said all that I could, that the expectations are that it stratigraphically fits in a rift system.

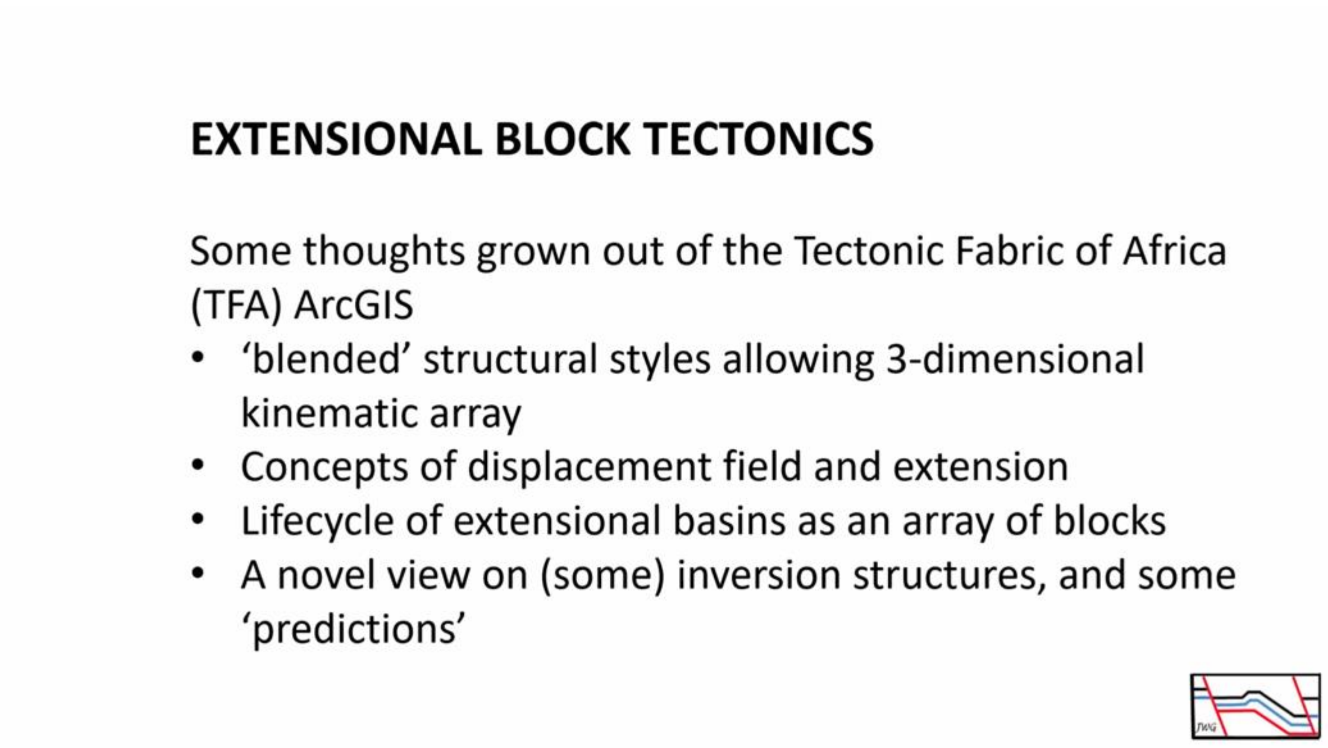
Jim Granath 06:14
Do Namibia or Botswana have any constraints or prohibitions against developing shale resources? Yes, fracking is absolutely taboo. As it is, in most countries in southern Africa, South Africa has banned it. So when you say unconventional, you usually imply unconventional techniques like, you know, directional drilling, I suppose would be okay. But fracking, of course, is out of bounds. And that's why we emphasize this as a conventional play. And these are conventional occurrences of hydrocarbons.

Jim Granath 06:53

Based on the Grabenhorst structure, is there a hint as to where the next well could be located? Again, that's the purpose of the seismic to start to get a handle on that.

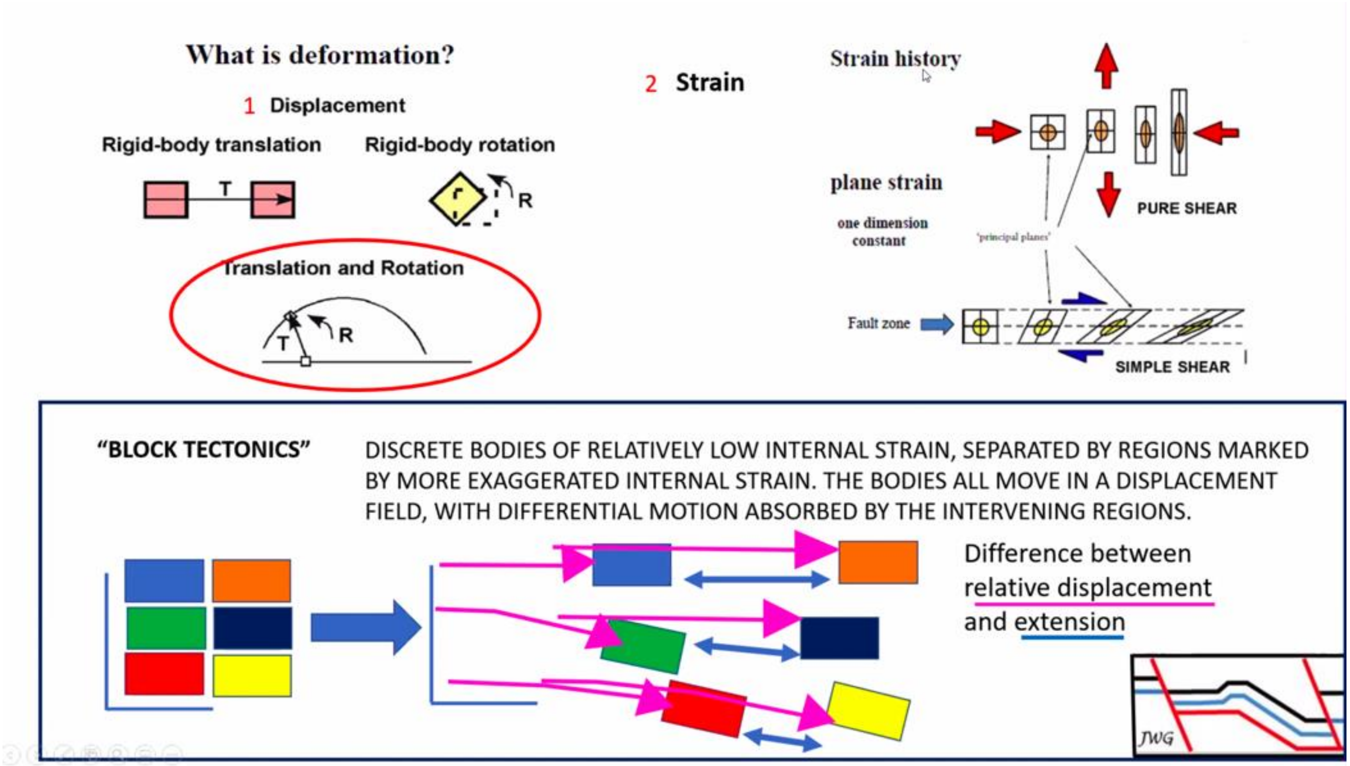
Jim Granath 07:05

Where do I think the shows and the wells come from? There's variable opinions about that. Some people think there's more than one source rock. And people, of course, have talked about a Precambrian source for some years, but nobody's ever really been able to find it. When they find something dark in color, it turns out not to be very rich. So stay tuned to be determined. And I'm not the guy really to ask about that. We're hoping that as we go along, we get some viable samples that can tell us more about the hydrocarbon chemistries themselves. I was hoping to get biomarkers that would tell us something like the Karoo biomarkers in bitumen that's in fractures down in the NAMA basin to the south. That turns up Permo Triassic biomarkers. I was hoping to get something like that, but so far, haven't heard that we have. Okay, are we ready to go forward?



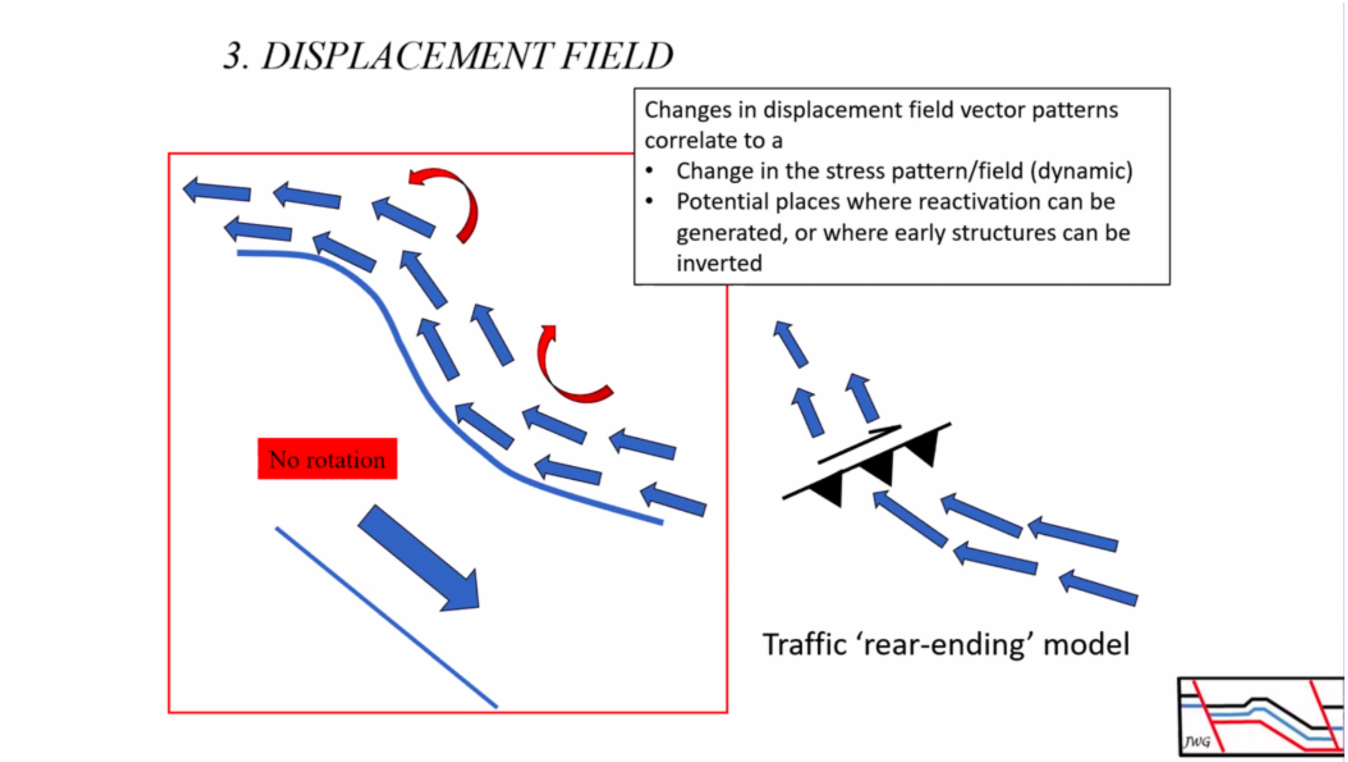
Jim Granath 08:15

All right, extensional, block tectonics. I'm a structural styles guy. I'm a structural geologist. I'm seeped in structural geometries. My specialty is recognizing structural geometries in seismic data. And for quite a few years, I taught the structural styles courses for PetroSkills, you know, when they were viable courses. So I'm always thinking in terms of the style we're looking at. And the implications it has for what the main direction of the structures is, or where's the dip line? Where's the strike line, that sort of thing. But I'm but I'm also keenly aware, since structures have to fill three dimensional space that basically, they don't exist unto themselves as a single structural style. You can either say, well, the different structural styles can be blended to make something work. Or you can say that subsidiary structural styles look like other things. So what I mean, for example, is that if you get into a strike slip system like California, you're going to find places where you have pure strike slip elements, you're going to have places where you may have extensional elements, you're going to have places where you have fold and thrust belts. They're all part and parcel of the same kind of system. So that brings up the concept to me that, that one of the best ways to approach this is to understand the displacement field that describes the relationship between these different things. This sounds very abstract now but I'm going to get to real examples very soon. And then, so with regard to extension, we have these transfer faults. Or we can have thrust faults because we can have situations where the displacement field is pinched, or places where the displacement field diverges. And we can have extraordinary deep holes, or we have places where the displacement field is parallel and at different rates. And that's going to give us a strike slip thing. So we're going to develop this concept of displacement field and what the difference is between it and extension. And then we're going to sort of follow some trains of thought that gets us someplace. And in the process, we're going to develop what I call the lifecycle of an extensional basin, viewing it as an array of blocks that are moving relative to each other, and that the extensional basins open up in between the blocks. And this leads, in the end to some novel views on inversion. One of the big geological mysteries of the 1980s is how can you reverse the stress field on a fault so that you change it from a normal fall to a reverse fault? Well, it's really very simple. And it also leads us to be able to do some predictions, at least one aspect of it, there are two types of inversion, which I'll bring up as we go.

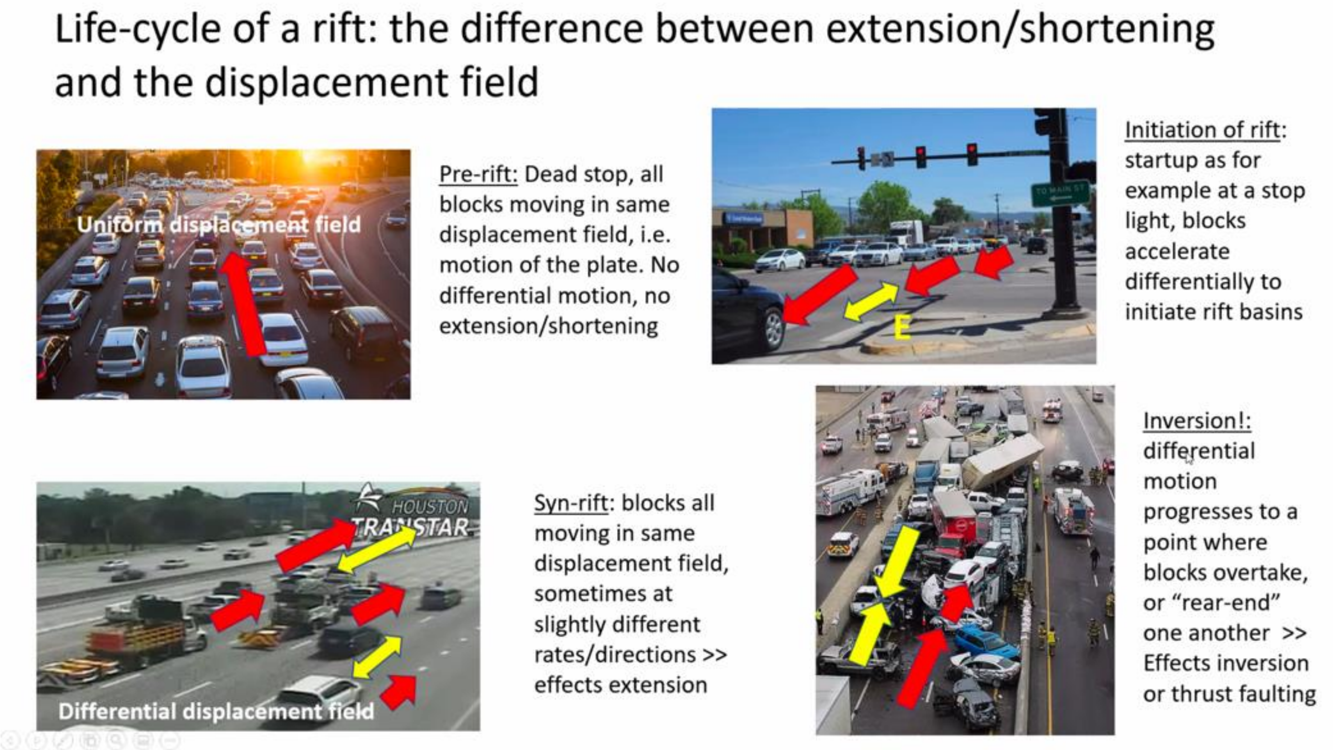


Jim Granath 11:35

Okay, so the top half of this diagram is straight out of a structural geology book. It's very dry. And all it says is that deformation, which is what the objective of structural geology is, the study, is composed of a displacement from A to B in terms of location, which is composed of a translation, and a rotation. It's composed of that, and an internal shape change or a strain, which is shown on the right. And I've just shown as an example here, to put you all to sleep, go back to your structural geology classes, where you've heard all about pure shear and simple shear, and then you went to sleep and didn't learn anything else again. We're going to go beyond that, forget about strain, we're going to talk mostly about the translation and rotation. That's what I mean by block tectonics. And, and so down here on the bottom, we've got six blocks, let's just think that they're, you know, the high blocks in a rift system or something like that, we're looking down on them in a map view. And so if we actually create a rift system with that, displace those blocks relative to each other, we go to the right hand diagram here. So the blue can displace on the pink arrow to this place, the orange farther out. And you can see that the displacement vector that describes a relationship is parallel, but has a different length. So, what we see when we go and shoot a seismic line, we don't see the pink arrows, we see the blue arrows, the ones that actually describe the extension, how far the blocks are from each other. But that's only because they've been displaced a different amount, relative to some other frame of reference. Or if there's a rotation involved, you can see the green comes out rotates, a bit separates from the blue, and then the black even shoots out farther, it has a little bit of a curve, and then it shoots out straight, doesn't rotate. So we have an extension that's oriented in a different direction from the original one, and then you get even more complicated situation with the red and the yellow. The difference here is that the displacement field, the pink arrows, tell us about relative displacements. And the separations between the blocks tell us about the extension or if they bumped into each other, the shortening that's involved. And so, all, everything I have to say really predicates on this distinction.

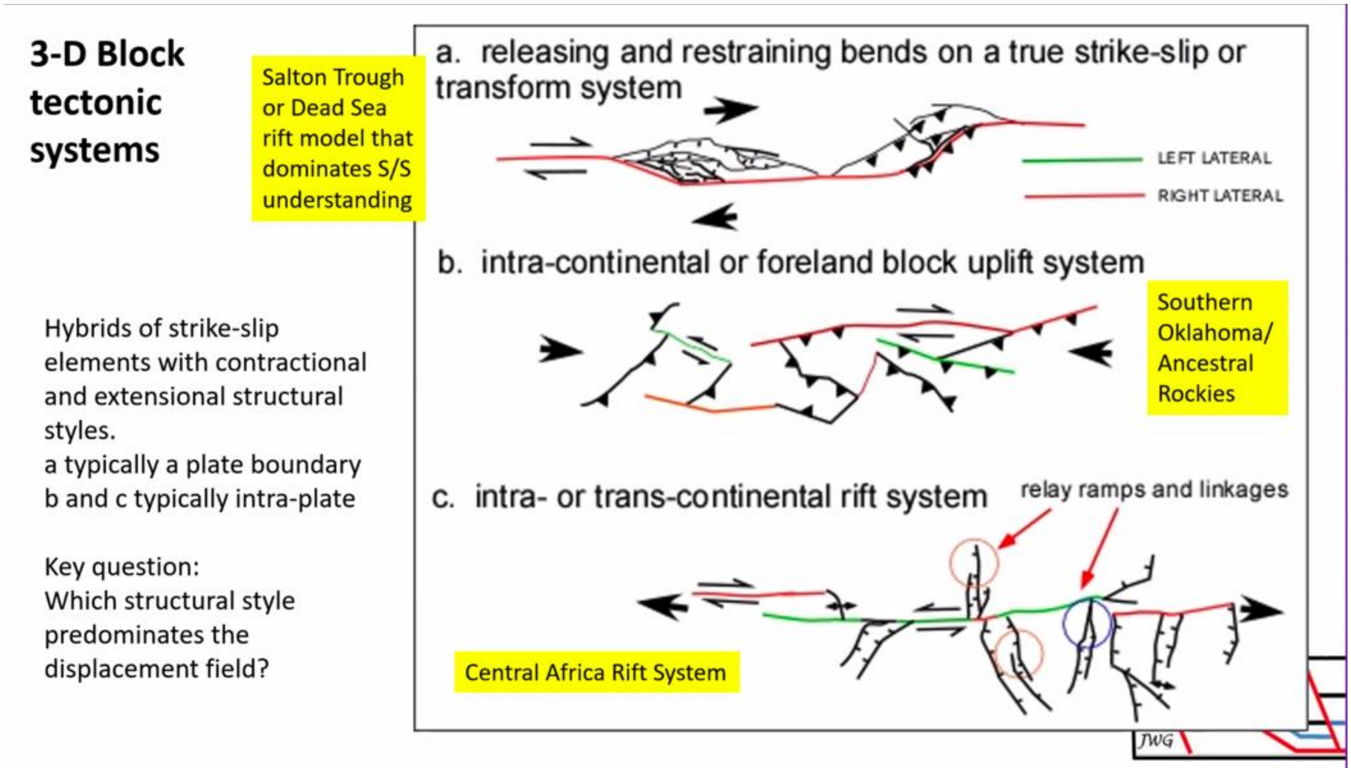


Jim Granath 14:10
In a normal structural geology course, people take the view of the left hand diagram here, where you can describe the individual particles in the body as having a displacement field or a displacement vector. So you can create a fold simply by driving the hanging wall up over a curved structure. And so the rotations that take place can be described by the collections of vectors at different positions. If you change the length of the vectors, you can open up cracks or you can drive little thrust faults or crushes or various kinds of features in the rocks. Purely kinematic, you know we're not talking about the stress or the strain. This is a case which really makes the argument that in a lot of dynamic structural systems, the stress is driven by the kinematics not by the push or pull of the region, which is normally what people think of, particularly an industry. So if you have a planar fault, things move down the fault, they stay together, they all have the same displacement vector. There's no rotation, there's no internal deformation. Now, if we go to a situation, we're going to break it up into two larger blocks, we're not dealing with discrete elements, we're talking about things the size of, you know, city blocks, or towns or fault blocks, or whatever. The displacement field can actually be punctuated by areas where it has pinching relationships. So here are, all the vectors are slightly curved, they're all about the same length. So, the blocks that are going in this direction are going like this at a certain rate. But then they meet this interface, where beyond that, the blocks are going in a different direction at different rates. So you're going to have some kind of a kinematic accommodation of those differences. And that's what happens when you've got, you've got inversion.



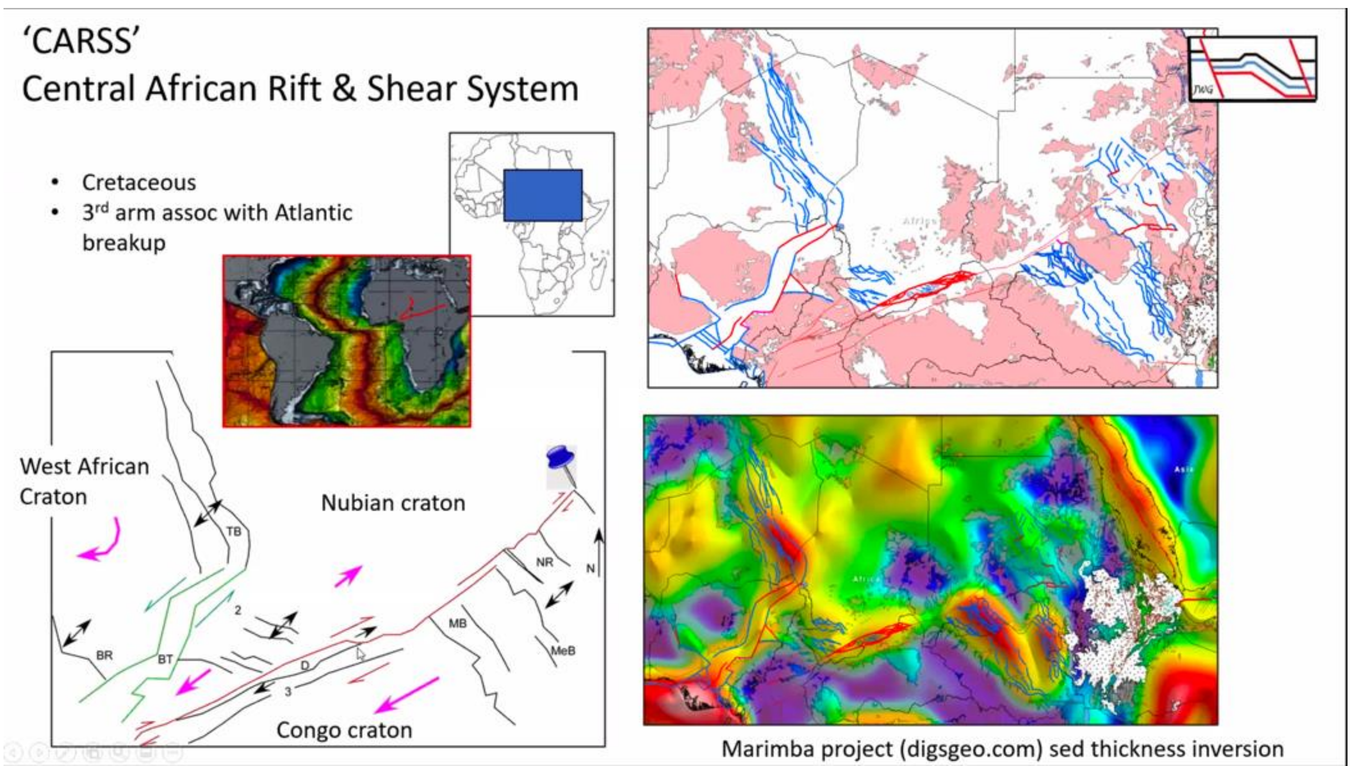
Jim Granath 16:15

So I think of this as a traffic model. So the life cycle of a rift, going from its initiation through from nothing to an initiation to the syn-riff development, where the blocks are all moving, to a situation where something happens. You can think of it the same way. Here in the pre-rift here, all this traffic is sitting there, the traffic light, the stoplights are on, everybody's motionless. So there's no internal differential motion, everybody's moving in the same direction, in this case, with the curvature of the earth and the rotation of the earth, or in geology, blocks that are moving at the same rate relative to each other, are still moving, but they're going with the motion of the plate. Alright, as soon as you initiate some kind of a difference, the initiation of a rift is basically the acceleration of some of those blocks relative to the others. So for example, here, when the traffic light changes, the cars in the front take off, and they take off and get going a little faster than the others. And they open up spaces. And those spaces basically, ripple through the whole line of traffic. So, although everybody's moving in the same direction, at the initiation of it, they're moving at different rates. And so you get different amounts of extension at any one particular time between any one of the cars. Then when everybody's up to speed, they travel along the highway at different rates, so they're more or less parallel displacement field, but the cars get separated by different amounts of extension. I'm going to go back to this traffic light up here in the upper right. Have you ever been at a traffic light, you're sitting there, minding your own business waiting for it to take to change, and you can take off and somebody takes off behind you before you do, and they rear end you? Did that ever happened? Anybody happened to me at the corner of Westheimer in Eldridge, when I lived in Houston. This is a case where you just change the relationship of these, these red vectors so that the guy in the back is going faster than the one in the front. And instead of an extension, you get a shortening, you get the accident. Well, as things go on along in the whole system, you get the same kind of inversion, when the block starts to slow down, for example, at the end of the rift at the senescence of a rift. And so one mechanism of creating an inversion is just simply by the kinematics of the rift process itself. And I call that syn-kinematic inversion. And I'll contrast that with the one that a lot of people are familiar with when we get later in the talk.



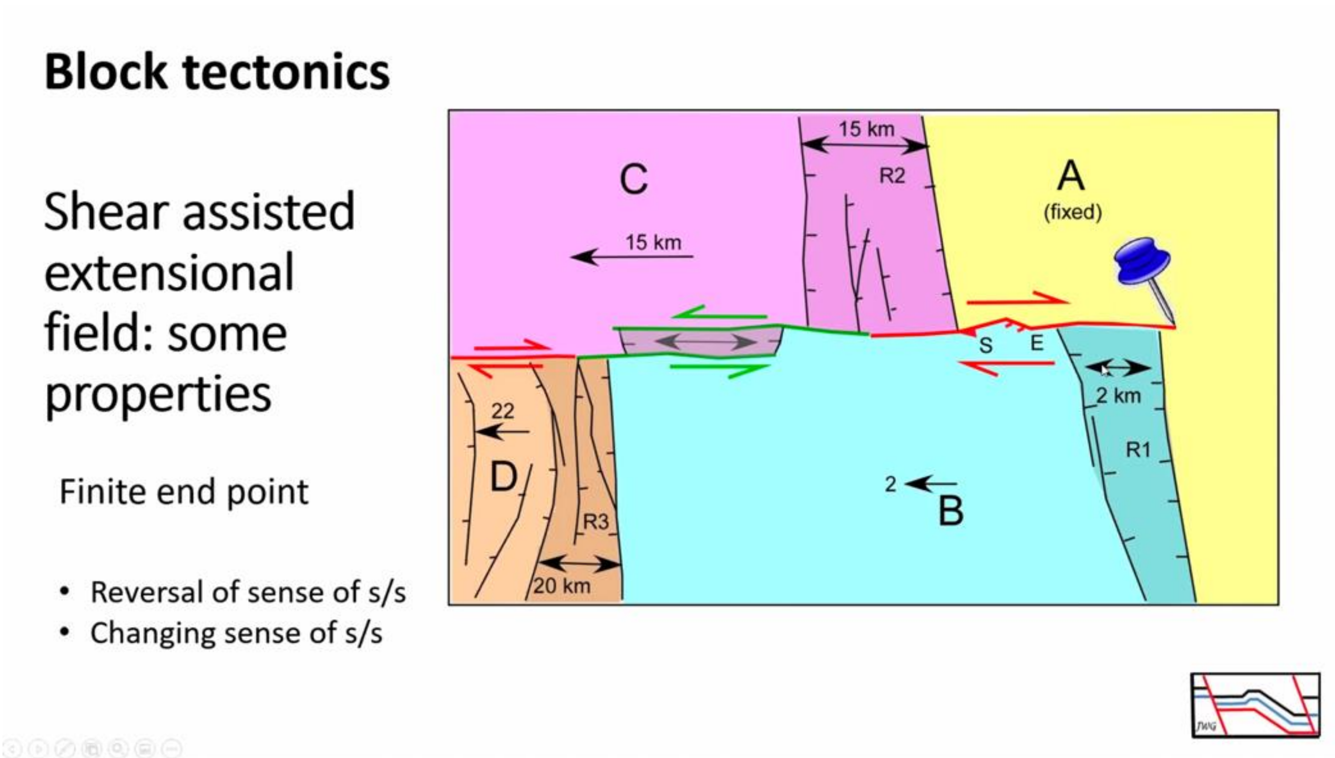
Jim Granath 19:39
So way back when, I started thinking about this, about 2015 and this is a slide out of the PESG-BHGS Africa conference, I think in 2015 or something like that. 2016 Maybe. And it contrasts different kinds of environments that this might happen in, and it brings together kind of pulls together this idea of a hybrid strike-slip element with contractual and extensional styles. On the top there, I've just drawn a single, right lateral strike-slip fault, with the classic, releasing and restraining bends, so you get extensional and compressional features of those bends. But the point is here that in that true strike-slip environment, the kind of thing that dominates strike-slip understanding today is based on the plate scale, San Andreas type, plate margin, transform fall, so that the blocks involved - when you ignore the restraining and releasing bends - the blocks involved are just the north side and the south side. And so everything on the north side is going at long distances, relative to everything on the south side. So the system is really driven solely by, these smaller scale structures are solely driven by these releasing and restraining bends and overlaps. And relative rates between the faults. If you look at the San Andreas system in the San Francisco area, it doesn't look like this at all. It's a number of individual almost dead straight faults moving at different rates. The ones farther inboard to North America are moving at slower rates than the ones out by the San Andreas. And so there, it's a bunch of slivers, all moving at different rates. But the important point is that the strike-slip magnitude is what's driving the system. So in a plate margin, that's large, you know, it can be hundreds of kilometers, it's much bigger than most of the smaller scale features along the system. So everything along a fault is either right lateral or left lateral,

for example. But if you get in a situation where there's a bunch of blocks that are moving relative to each other, and it's the motion of the blocks that's driving not only the extension, or the shortening, but also the strike-slip components, then that's a different sort of situation. And depending on the block arrangement and their motion relative to each other, you can get mixtures of right lateral and left lateral strike-slip systems, which are basically just the transfer faults connecting the blocks. We'll usually ignore those in the industry. We go right across them with a seismic line. And you might see a little disturbance in the in the reflectors, but you've crossed a major structural features. And so I started to really learn about this when I was working in southern Oklahoma for Conoco, and then sort of since developed the concept of how the ancestoral Rockies might have developed in a similar sort of way. In a continental rift system, it's basically the same sort of idea except rather than bumping into each other or overlapping each other or having the whole system being shortened. We're extending the whole system. And so we get the typical things that you'll hear about in a course on structural interpretation, like relay ramps and linkages, and all of that. But you can get different kinds of relationships as you go along the transfer faults that connect up the different basins. And that's why I call this an intra or trans continental rift system. It's internal to the continent. And it might cross the continent. And we're going to look at the situation in the Central African Rift in just a minute. So the key question is, what's the dominant structural style, in A it's the strike-slip system that all the California schools taught us about in the 60s. And in B, and C, we sometimes don't even recognize strike-slip as being component of the whole thing.



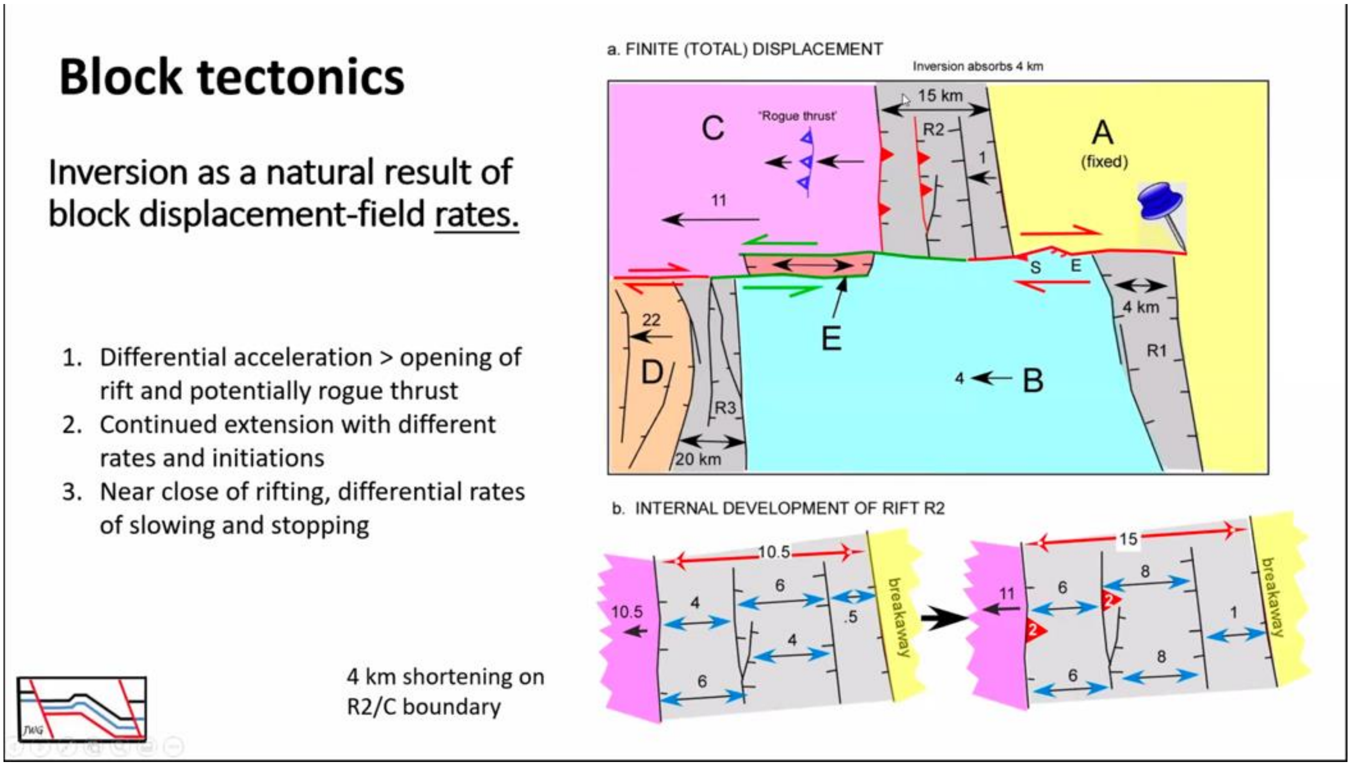
Jim Granath 24:06

Alright, so let's look at the Central African Rift and shear system, what what I call cars. So it's Cretaceous in age. It basically points inland from the Niger Delta. It's basically the third arm of the breakup of Africa, you can see the transform on the Guinea coast. And then the extensional margin going farther south, they sort of stick into the middle of the continent, if you replace the whole thing together. They're just 1/3 of the triple junction. If you do the same sort of thing out of the TFA, as we did before, with the southern system, you can see the basement outcrop here in pink. And then I've just put all the normal faults in blue, various systems, and I've put all the shear systems in red. And so you can see how they fit together kinematically, all the extension up here in Chad gets fed into the Benue Trough, and eventually into the triple junction. If you go along the Central African system, it basically starts way over in Sudan at a point where nothing's displaced. There's a pinpoint there at one little rift, and then everything accumulates on both sides of the [inaudible] for some distances. And so if you add up, those displacements that describe those openings, you could tell what kind of and how much strike-slip motion there ought to be along these transfer faults that connect the different basins. Down here on the lower, lower right, we've got the Marimba sediment thickness map again. And you can see sort of where the deep blue is, you can see that the basement is outcropping because we're basically having zero sediment thickness. And so you can see where a lot of the thicknesses are accumulated, the Red Sea doesn't participate in this, the actual point of initiation of the whole thing is right there in Sudan. So tying it all together again, here's our Congo Craton, just the northern side now, across from the Nubian Craton. You can see the shear zone running along there various kinds of rifts and the Chadian rift systems that are on the south side. Since they're extending everything on the south near the Congo Cratons pulling away toward the west makes this a right lateral system. As we come down, it jumps to the north and actually has a pull-apart basin, a pull-apart basin, it's probably the best example of a pull-apart basin I know of that's highly petroliferous Then there are some linking systems across here where this corner of the Nubian Craton is breaking down. And that connects over to the left lateral system that the Mali rift systems are feeding into. So the West African Craton is doing a slight rotation and moving to the west, relative to the Nubian opening up that as a rift and this is a transtensional system. So you can see how the elements fit together. This is not a particularly new idea. I think I'm one of the first people it's followed along to some of the some of the natural conclusions, though.

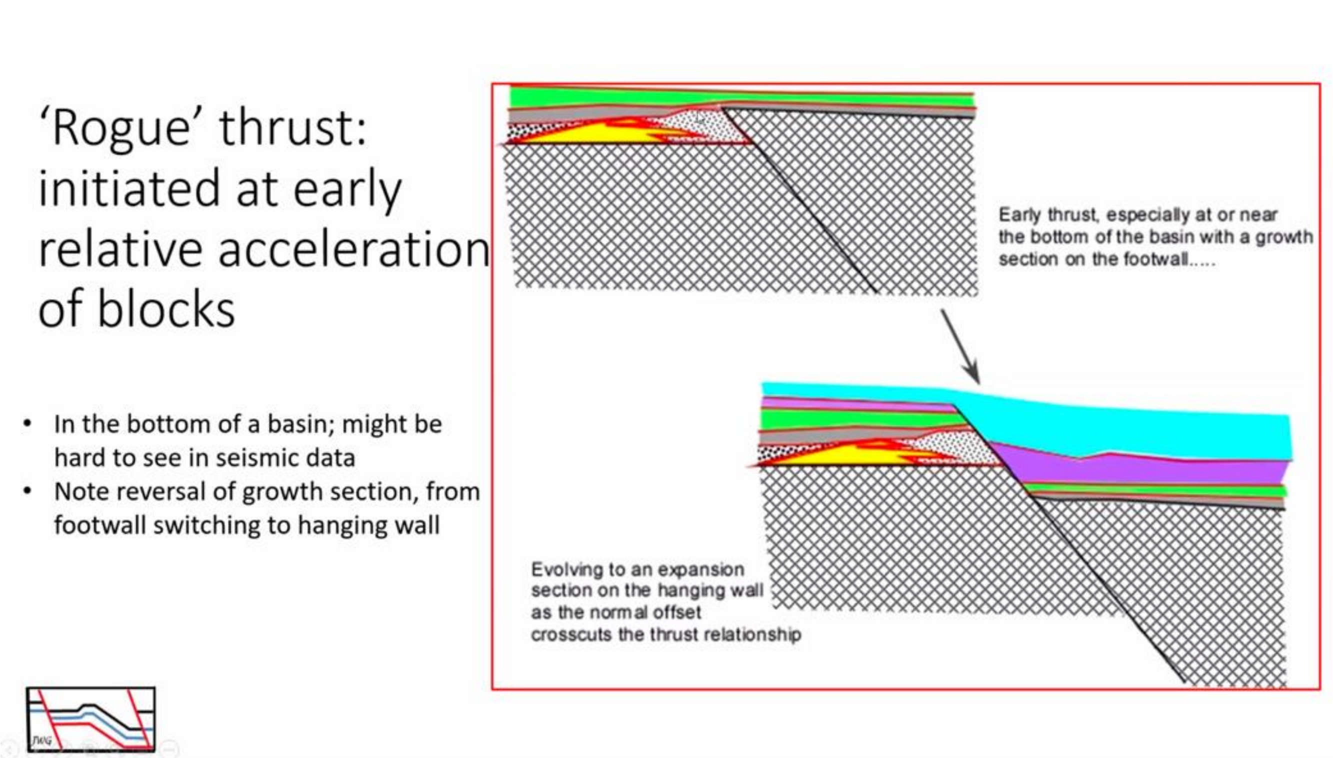


Jim Granath 27:44

So let's look at that in a schematic diagram. And let's just sort of change the rifts a little bit, so we can invent our own relationships. Here we've got block A. For our practical purposes, it's fixed and everything moves relative to it. And down here, we get Rift Valley one that opens by two kilometers of extension, well, two kilometers of extension there translates into two kilometers of displacement of this intact Block B away from a. And so we're those two are in contact, we've got a right lateral relationship. And you could have the releasing and restraining bend structures, everything that looks like a strike-slip fault could happen right in there. Then on the north side, if R2 opens, and it opens with a 15 kilometers of extension, it would shove Block C 15 kilometers in displacement toward the west. And so since that moves 15 kilometers toward the west, relative to A and B runs those two, you have 13 kilometers of relative strike-slip offset on a left lateral system between those two blocks in there. And so you can see over here, we would everything that tells us, right lateral, right lateral, right lateral, and if we mapped our way across past the end of this rift, everything here would tell left lateral, left lateral, left lateral. And the same thing could happen here, when we flip over from Open D down here at 22 kilometers opening, that's much more than the 15, seven kilometers more. And that opens, changes flips that over instantaneously till to the right lateral system. That assumes and this is a finite thing. This is the sort of situation we would find if we went up, looked at it in the field after everything has happened. But as it's happening, it's not that hard to imagine that R2 might not open early on. And R1 may be fully completed by the time that opens up so that as the rates of these different blocks changes and their relative position changes, you can actually reverse the sense of motion on the faults, on the strike slip systems.

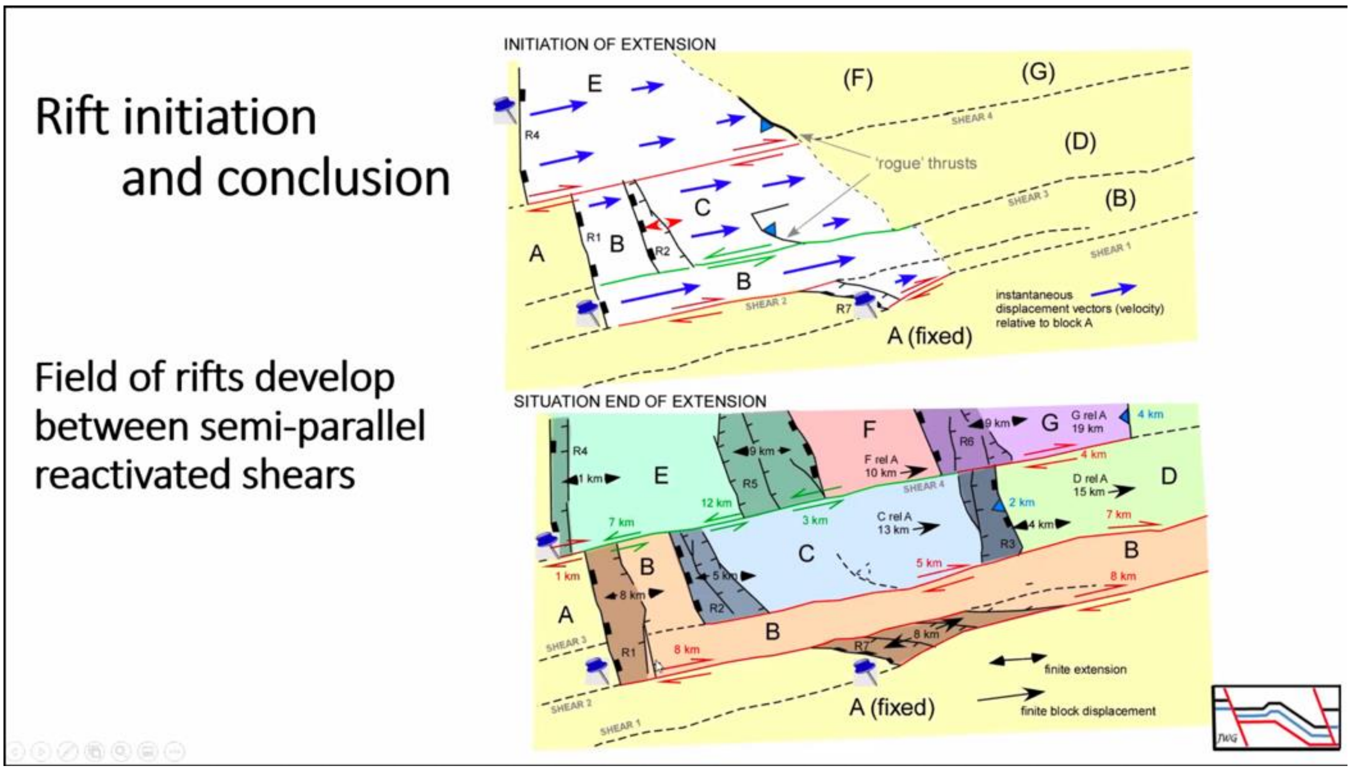


Jim Granath 30:08
Alright, let's make that even more complicated. That was the finite situation, what if we look at it from the point of view of our kinematic model, or traffic model, for example, here's the same situation, only I'm opening this 4 kilometers, B is showing 4 kilometers to the west. But everything sort of accelerates more or less the same rate, and it's sort of slows down so we don't get any strange structures. But what if things are happening in R2, it might have a very heterogeneous architecture, it might have different rock types with different geologies. Down where the detachment is taking place, it might have internal faulting systems with different amounts of displacement. And so in the end, if it displaces 15 kilometers to the west, but Block C really only moves 11 kilometers to the west, then there's a four kilometer problem here that can be accommodated by shortening or overlap or inversion type structures within the basin of itself. Even just the same, the very same kinematic systems. Now you think of it again, let's say this starts to open, starts to open at a certain acceleration, and C doesn't accelerate fast enough to keep pace, then it can generate what I call a rogue thrust over here in the middle of the block, that just sort of keys into the fact that C had a lag time in its development. And we might develop a compressional structure until C starts to get up to speed. And that's what all this is about, the internal development of rift two.



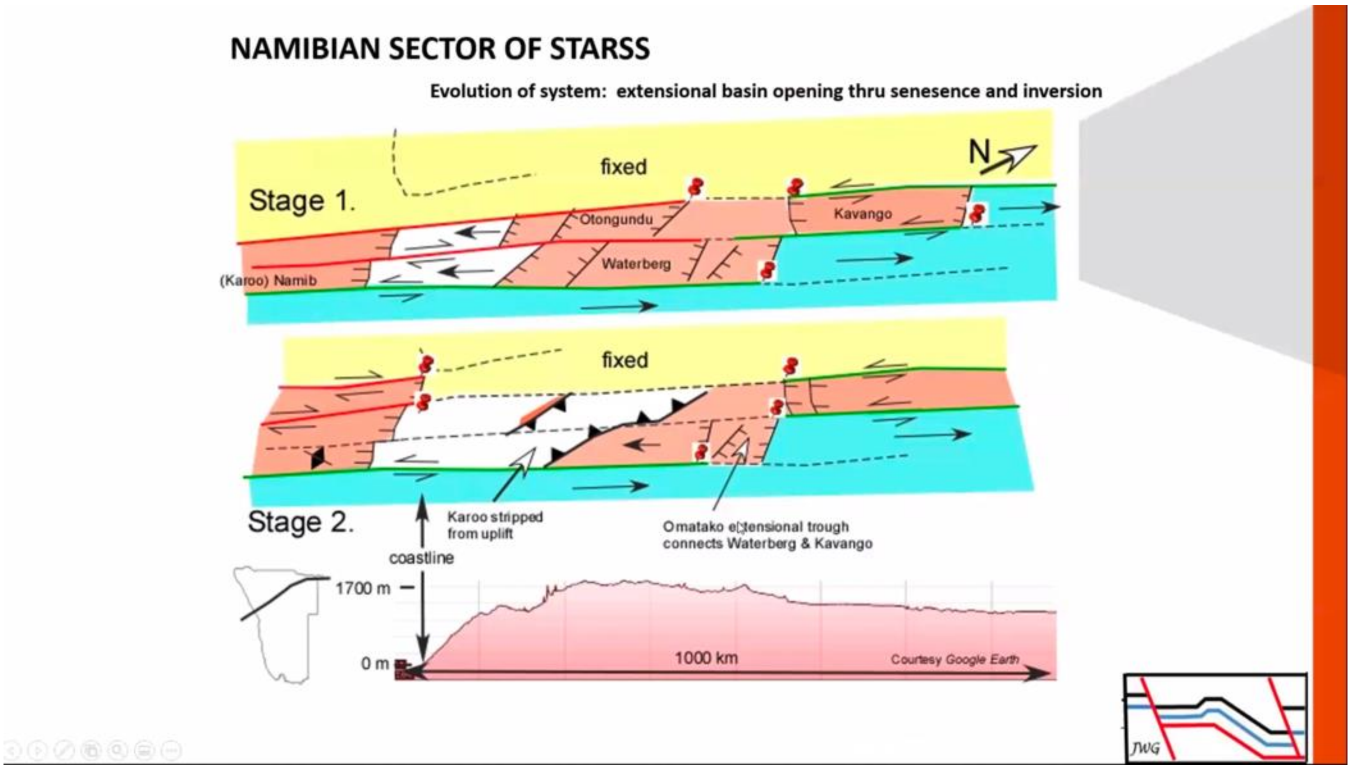
Jim Granath 32:01
Okay, so a rogue thrust. Anybody ever seen one? I've been looking for 'm. The trouble is that if they're early in the history, they're going to be at the bottom of the basin. And our seismic information often just goes away, just dies in that sort of situation, or is not very clear, and unless you would be looking for these things, you may not be able to find them. But what we would see is an early heave developed by the hanging wall, the block being thrust up, and we might actually the way we would recognize it, it would develop some kind of a growth structure here in the foot wall, to indicate that the rocks had been accumulated on the down thrown side, classic stuff for [inaudible]. And then it would get overlapped by a section. And it may even, later on, evolve into a normal fault. So we would get a normal fault section, what's called a negative inversion developed right across the positive inversion. So you would see these kinds of very strange relationships you would see hanging wall thicks, shallow in the section and you would see footwall thicks low in the section. And it's this observation that this is in here, that would give us a clue that we saw something like this happening. Did I hear an oomph, an objection or a question there? I see something about good for prospects, yeah, that, this section would be a fabulous target the drill. You can think of the sedimentological situation off to the central part of this on the Graben there may be some source rocks developed into a marine embayment or even a lacustrine environment. This would tend to be course sandy clastic type stuff. It would be terrific in the sense of prospecting. Alright, so what about multiple sub parallel shears? That CARSS system was just one, but this is what got me thinking about it. The southern Africa system is composed of multiple shears. And it's composed of conventional rift basins and basins that are developed parallel to those shears. And when you put it all together, we think that the very simplest hypothesis is that when the cape fold belt was developed down on the southern side of the continent, the Kalahari craton kind of rotated and shifted a little bit in a left lateral sense relative to the Congo craton. But then remember that each one of

these cratons has a lot of those internal boundaries from its older period of construction, things like the Oklahoma Aulacogen, and those may have been reactivated and we don't know about that. So it may be that the cratons are breaking up into different blocks moving relative to each other. And depending on the rates in the sense of offset across the STARSS system we could get right lateral and left lateral relationships scrambled up. So that's the idea we have we have displacement vectors. Over here in the east, we have the divergence of the Zambezi Graben in the Luangwa Graben and these others that it suggests that this part of Tanzania and Madagascar are pulling off at a faster rate than they are to the rest of it. And that basically, with the STARSS system being sub parallel to the boundary of the two cratons, that we develop these shear related systems rather than the classic extensional system, so they have short rift segments with long transfer fault segments,.



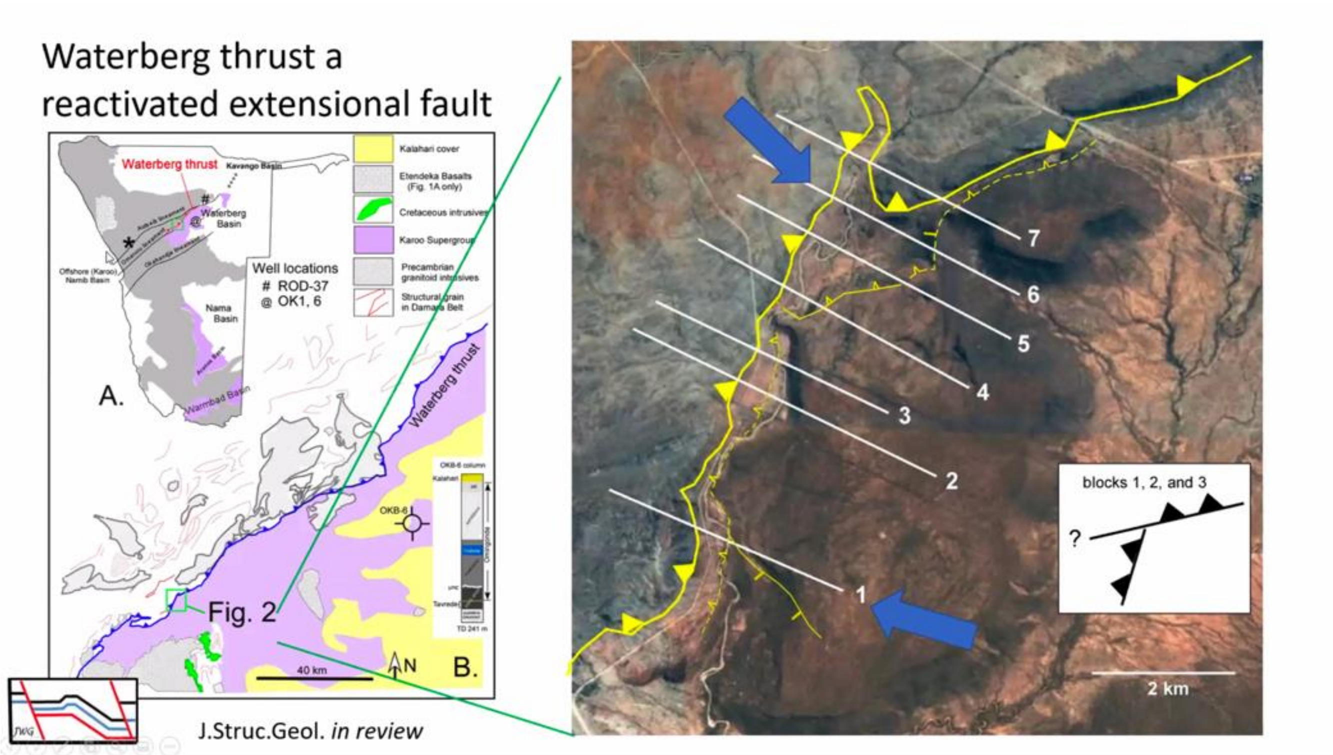
Jim Granath 36:08

Then we could make up a system of that. So down, down on the bottom here was the finite element thing with A, again, being fixed. And we've got 1,2,3,4 shears inherited from the basement. And we start to develop rifts as short segments across those individual slivers if you like, of continent, and we can develop the basins at different rates of opening and different amounts of displacement. So down here, B, opens across rift seven, at eight kilometers, so we have eight kilometers of right lateral motion over here, that's going to be balanced by eight kilometers of right lateral motion over here in R1. If that's anything different than we're going to have to have another structure in there to accommodate the difference in the displacement. And so if block E slips away from A on rift four here, it only opens up one kilometer, it's only moving one kilometer to the right relative to A, but all this stuff down at B and C, is at eight and 13 kilometers, then these are going to be left lateral systems, as opposed to the right lateral systems down here. Okay. And then if D, for example, is fixed over here, G is moving to the east, at four kilometers, relative to D, then we're going to get a thrust relationship of four kilometers in this position right here. And I think we see that in Africa and a lot of places where these individual block uplifts are just sitting out in the middle of the plains. Like the one I pointed out by Lake Malawi, there's [inaudible] data that suggests that that uplift was at least partially developed during the Permian. Alright, well, ordinarily, you would think that an extensional system is unlikely to have any kind of thrust relationships, but it all depends on the displacement field. So it'd be a great little project for a student to get out there and get some samples and see if we can date the relative uplift of that [inaudible], and then do the petro genesis of the [inaudible] to get an idea of the depth of development and then the afterward, the thermo chronology, to trace its uplift history. Fantastic project. Alright, so along the way, I mean, if we then think about that, in terms of how the displacement field gets generated, we can look at this diagram here, which is a hypothetical initiation of extension, we have the same block A fixed and we just start to shove these, open these rift basins at different rates, with the blue arrows are being different. And we can, relative to this area out here that hasn't moved yet, we can get the situation where we could develop some of these rogue thrusts. Or in the end, we could develop thrust faults that I haven't put on here other than this, this restraining bend kind of thing.



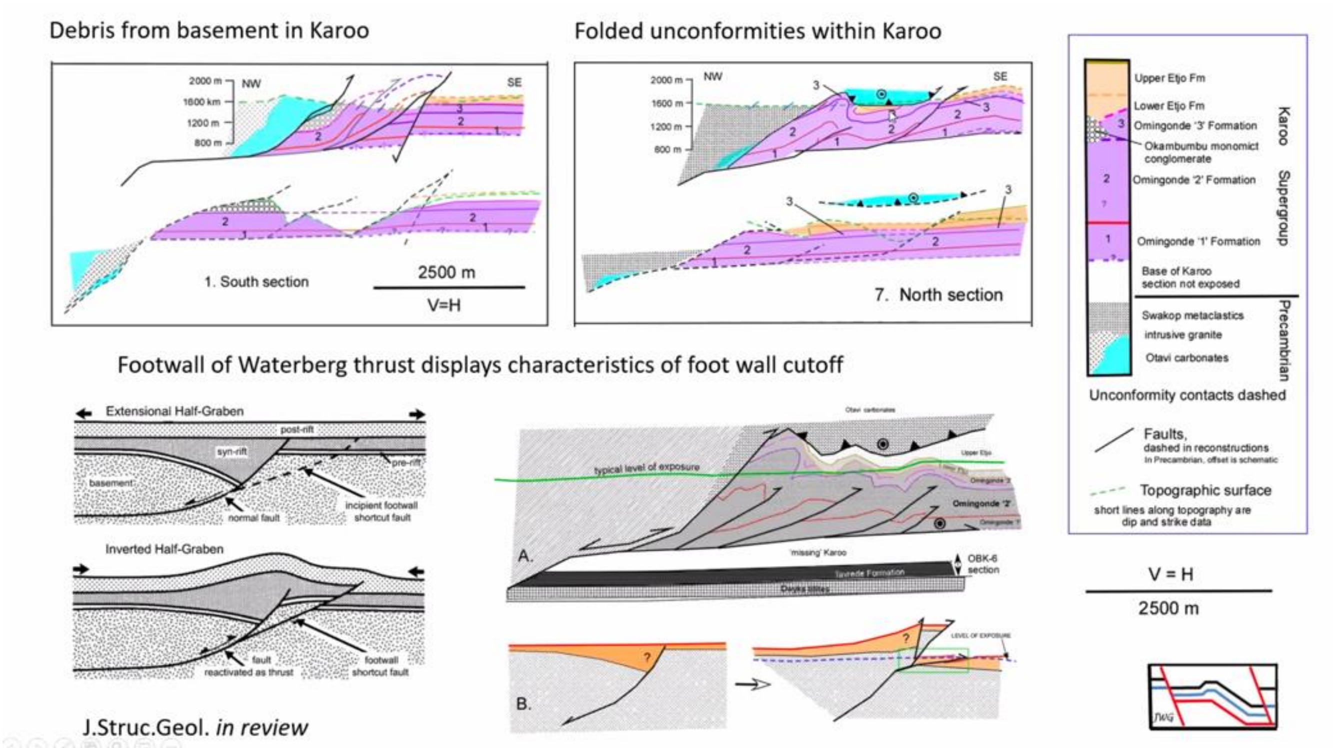
Jim Granath 39:27

And that's the basically the argument or the mode of thinking behind this diagram I showed you about Northern Namibia, with the development of these basins in the central part of the system. And they're opened and because they continue to move, the blocks are destined to be upthrust over their neighbors as they are on the Waterberg thrust here.



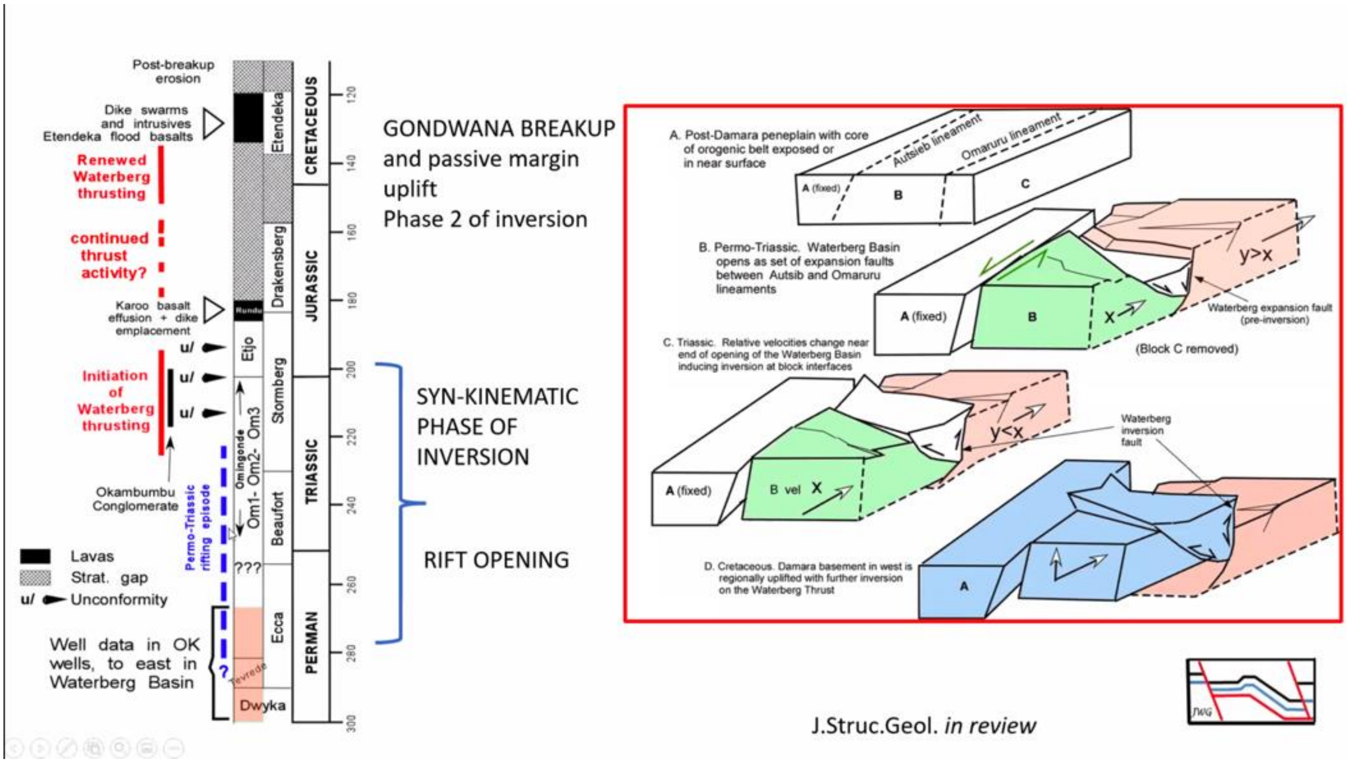
Jim Granath 39:54

Okay, let's look at that. Here's here's the geologic map of Namibia, the basements in the gray, Karoo is in the purple or pink or whatever you want to call it, down here in the Nama basin which is a epicontinental basement but here in the Waterberg, we've got internal faults and then this whopping great out of character thrust fault called the Waterberg thrust. Some people including geologists from Wurzburg University a number of years ago did a project mapping a small area along the Waterberg thrust. And Ansgar Wanke who works with the Recon project was part of that. Ansgar and I went to visit this because it was a classic place. They mapped it in great detail, which I'll show you in a minute. Think I'll show you in a minute. But on Google Earth, it looks like this. Here's the Waterberg thrust that it separates these gray and red areas which are upper Precambrian meta sedimentary rocks and meta marbles and granites and things. They are basically the crystalline basement for the Damara thrust across the Waterberg thrust, which look at the shape of it, up on top of Karoo. And so what we did was we took their map and developed some nice balance sections across it to develop the relationships between the structures in the Karoo, and the Waterberg itself. We found two places that were of real significance. Down here at one well, two of them that you can just pick up and talk about all of them had some sort of nuance. This is all been submitted to the Journal of Structural Geology in a volume that's devoted to John Ramsey. If anybody knows that name from structural geology, the classic folding and fracturing of rocks and a few other papers. He passed away last year, and this particular journal is going to be dedicated to him. So we did classic restored sections in the seven locations. The one down here shows that there are conglomerates that are derived from the marbles in the basement rocks interdigitated, with the Karoo, that says that this thrust fault developed during Karoo, at least started. Ten up here on the north on five, six and seven, where this big reentrant takes place, there are subsidiary faults cutting out into the Karoo. And they're also unconformities, between different members of the Karoo that cut across the older members.



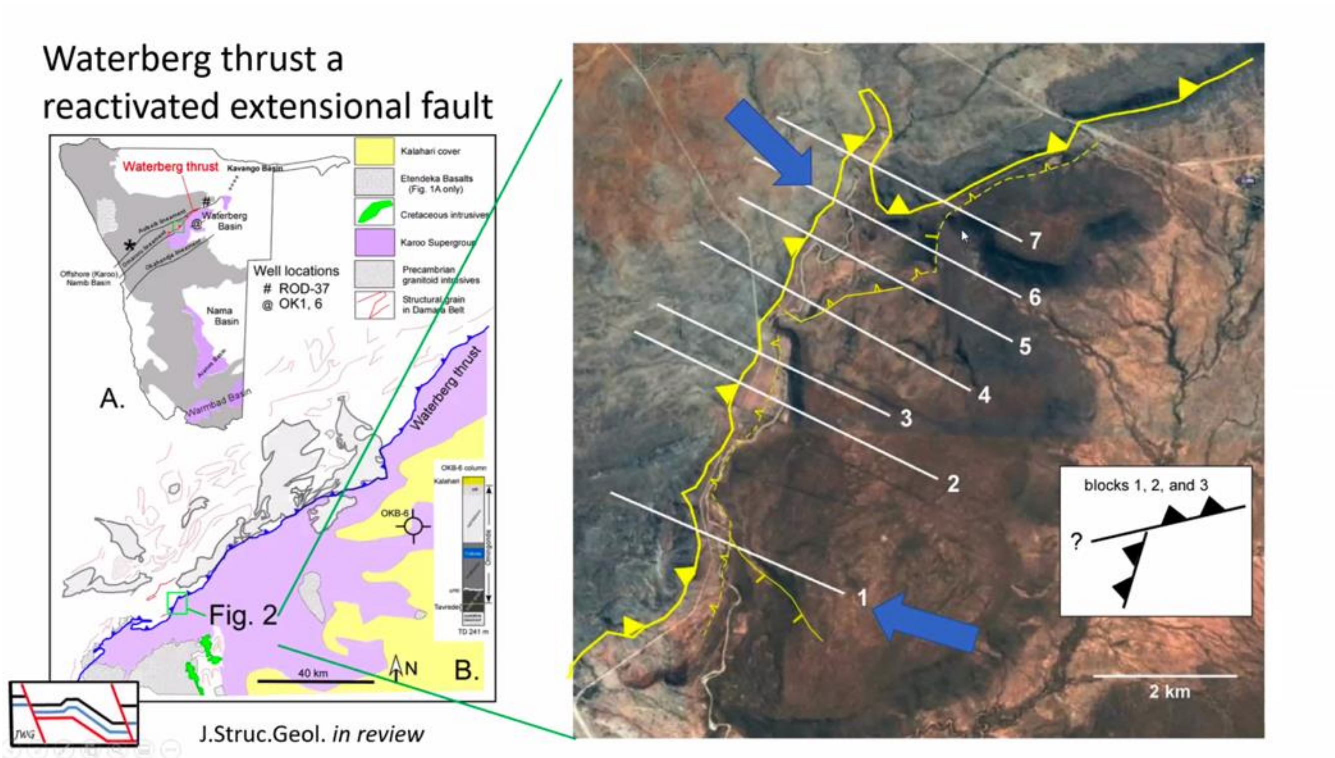
Jim Granath 42:55

So they suggest that the Karoo was actually folded. And in erosionally cut across by elements of the developing system. Here's that unique conglomerate developed here. And then we restored all these basically to get an idea about how far the hanging [inaudible] had been brought in. And then this is the piece of the Northern part of the thrust of the basement coming in right there. Okay, so the whole thing smacks of the footwall cut off idea on a on an inversion structure. So here out of the literature, classic, Cooper et al paper from the late late 80s shows the idea of a rift developing and then being inverted. And because of the stresses and strains that are involved in it, they often develop a footwall cut off, that cuts off the corner of the basement here that reduces the work that's involved necessary to accomplish the short end. And so you can get these wild kinds of structures. Well, if we stack all these together, in the same model, we see much the same sort of thing: the footwall comes up and it actually is folded around some of the structures in the footwall and some of the unconformities in the footwall cut across folds, tighter folds below them and that they themselves are tipped up and cut by the thrust. So it suggests a very progressive sort of development like I try to convey down here. So the level of exposure is within the basement, up until the Waterberg thrust and then we get into the Waterberg basin itself. We don't know the bottom of that at all. We just know that to the west, the whole roots of the basin are completely thrust up and on top of the other. So the whole thing smacks of a footwall cut off. And the relationships of the stratigraphy on the one hand and the folded unconformities on the other suggests that that all develops right at the tail end of the development of the Karoo rifts.



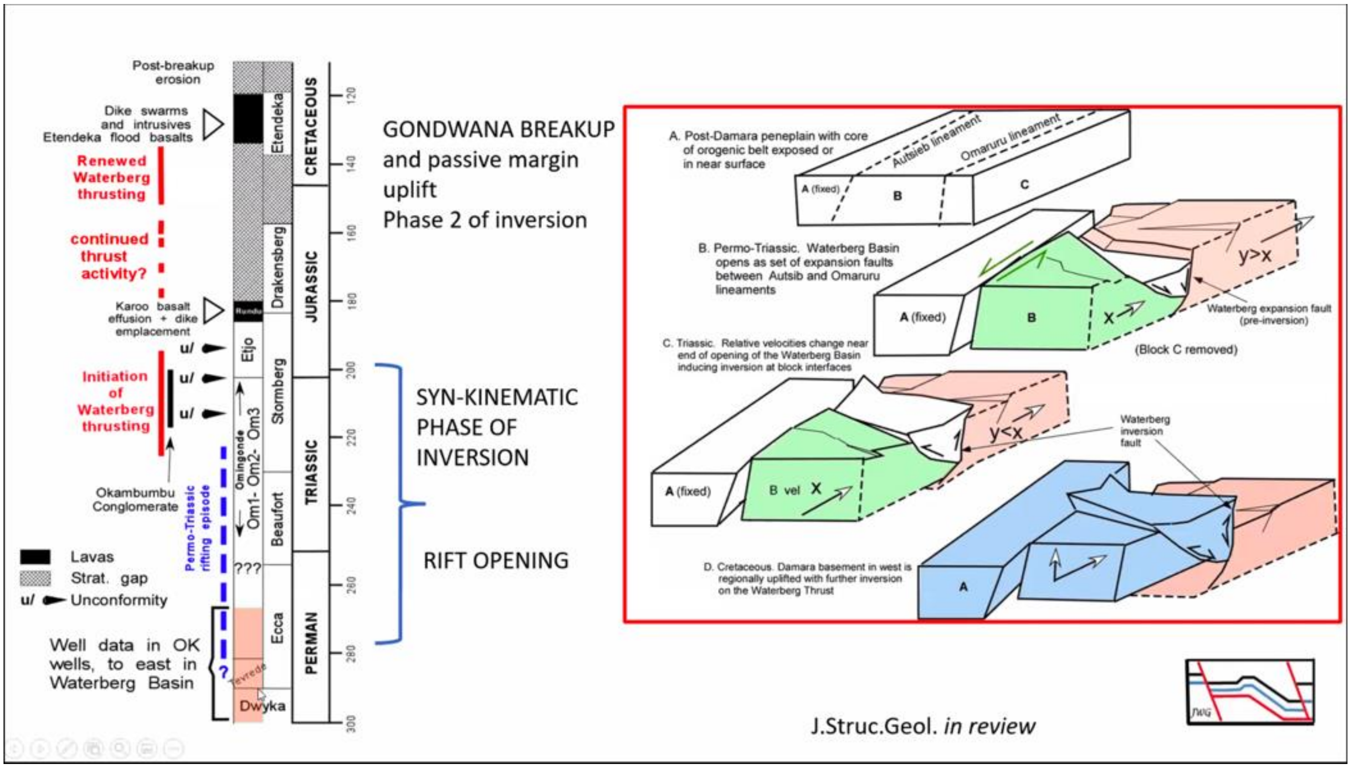
Jim Granath 45:23

So here's a timeline I've been trying to get get this into typical usage and it shows the period of time when the riff took place and blue, starting back down in the Permian comes up and then the initiation of the Waterberg thrusting is right here in the Stormberg group, the top of the Omingonde. And that is dated by those Triassic vertebrate fossils, the dicynodonts, etc. The mammal-like reptiles that are involved in the Omingonde part of the section. That's what this is about. These are individual unconformities that are cutting across everything.



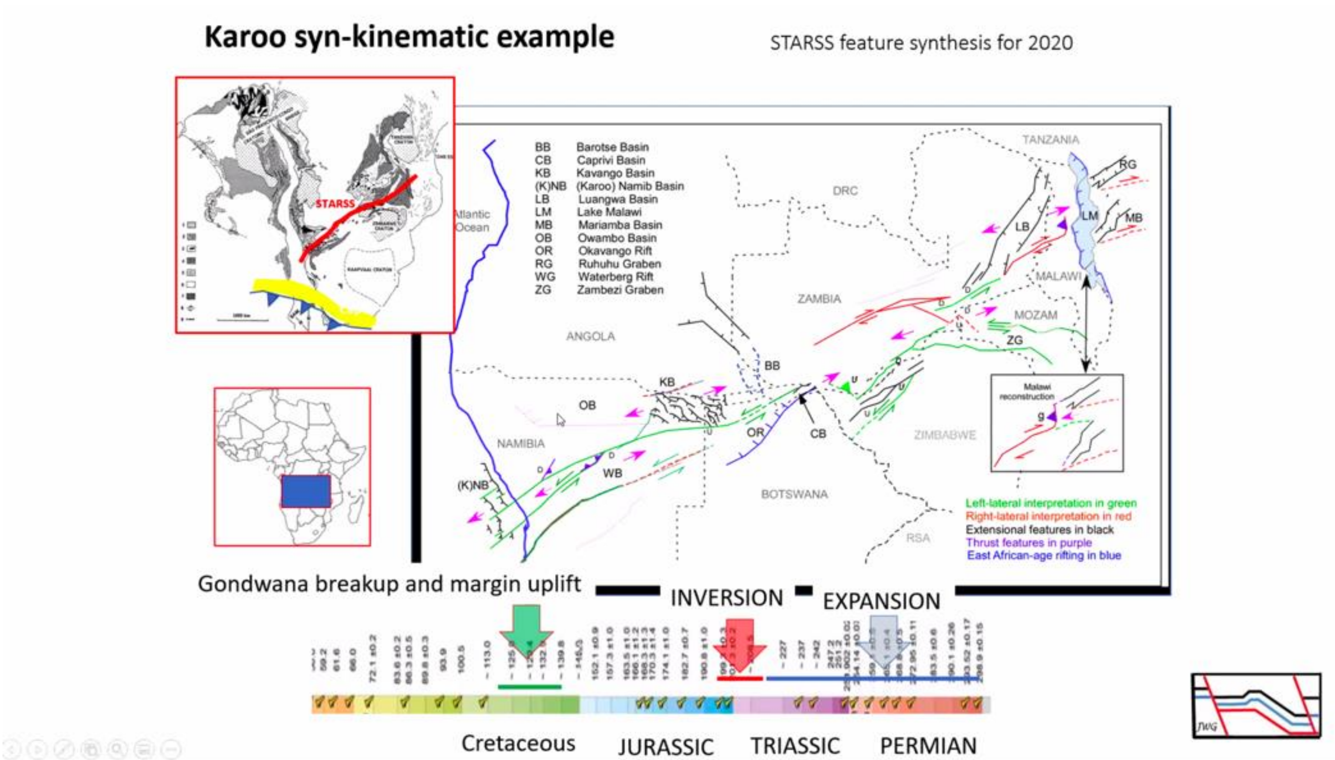
Jim Granath 46:07

And then I forgot to mention that at the Etjo, the base of the Etjo here has a special geologic formation that is only locally developed within a few kilometers of the rift itself. So it suggests that that is a sedimentary blanket that's related to the topography related to the rift.



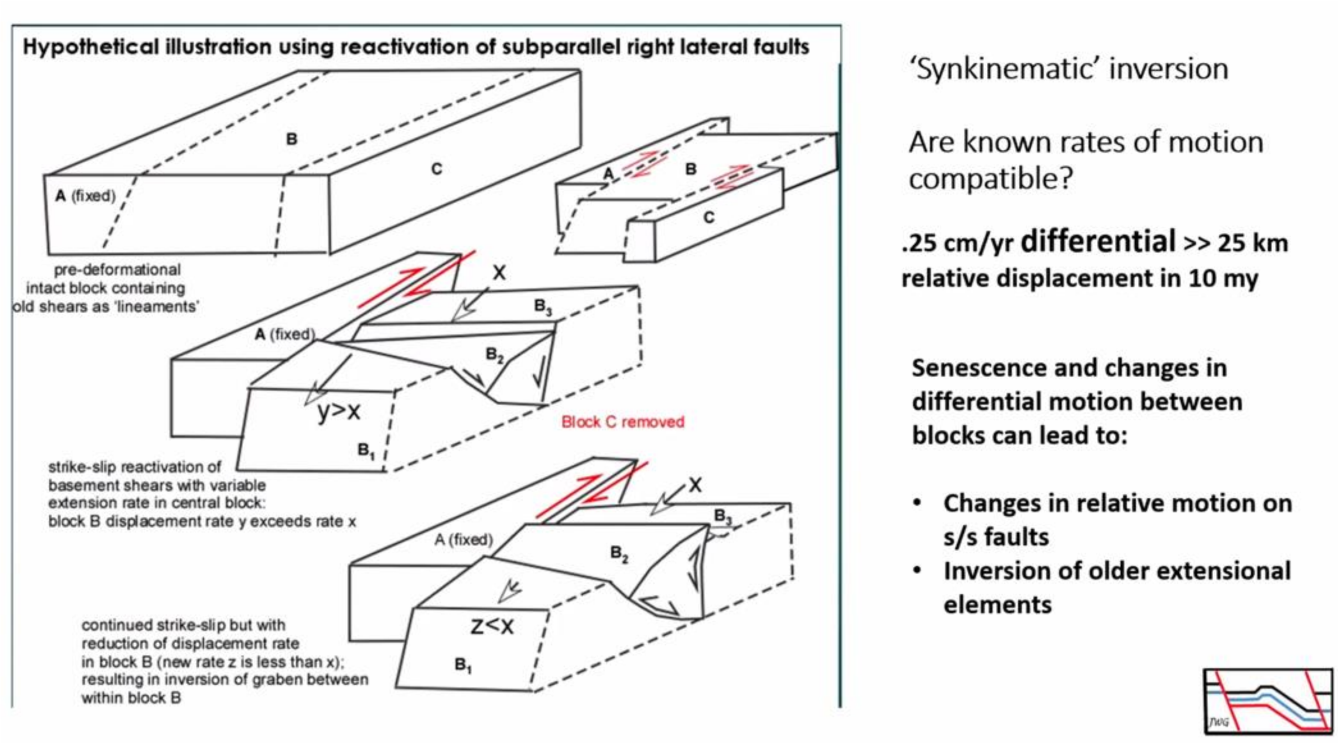
Jim Granath 46:34

Okay, so we've been developing these timelines. If you work the regional story in from the literature from the [inaudible] and everything, you come to the conclusion that the Waterberg rift was up here in the latest Jurassic an earliest Cretaceous, which is the major uplift of the hanging wall block. But that can't be if it's shown in sedimentary elements within the Karoo itself. So it looks like it's got two phases, one that's related to the block dynamics itself. And then another that's related to the superimposed shove from the uplift of the whole continental margin. Taking it through some block diagrams, if we start here with the two lineaments that outline the Waterberg, the Autsib to the north and the Omaruru lineament to the bottom here, we can go through four stages we can open the Rift, by having B move to the upper right, slower than this part of B the red part of [inaudible] So the motion is larger in this block toward the north than it is in this and it opens up that little rift body which is part of the Waterberg basin. And we're going to take this as the Waterberg thrust right there, expansion fall. Then we come along in the Triassic while the Permian is still being deposited. And we change the relative motion of those so that they're both moving in the same displacement field in the same direction, but with slightly different rates. This time the red is moving slower than the B than the green. So B rear ends rear ends the red and as a result pops up the block in the central part. This is the initial stage of the Waterberg development. And then by the time you get to the Cretaceous and the whole margins being slammed and uplifted, everything B, the Waterberg block and even A the part of A that's fixed, this all gets jammed up and uplifted so that everything gets uplifted relative to the red part of the Waterberg basin which preserves the Karoo sediments. Everything over here is all in basement, and the Karoo's all been stripped from it.

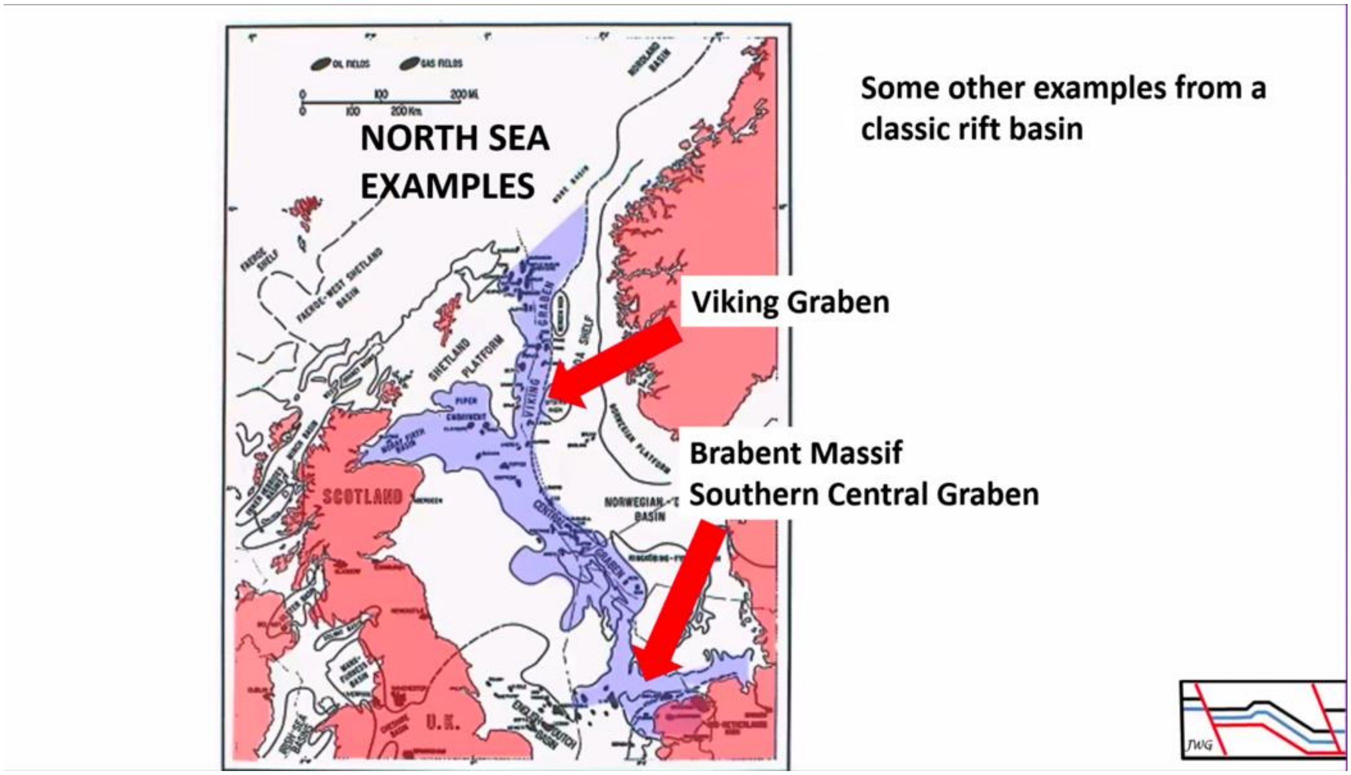


Jim Granath 49:08

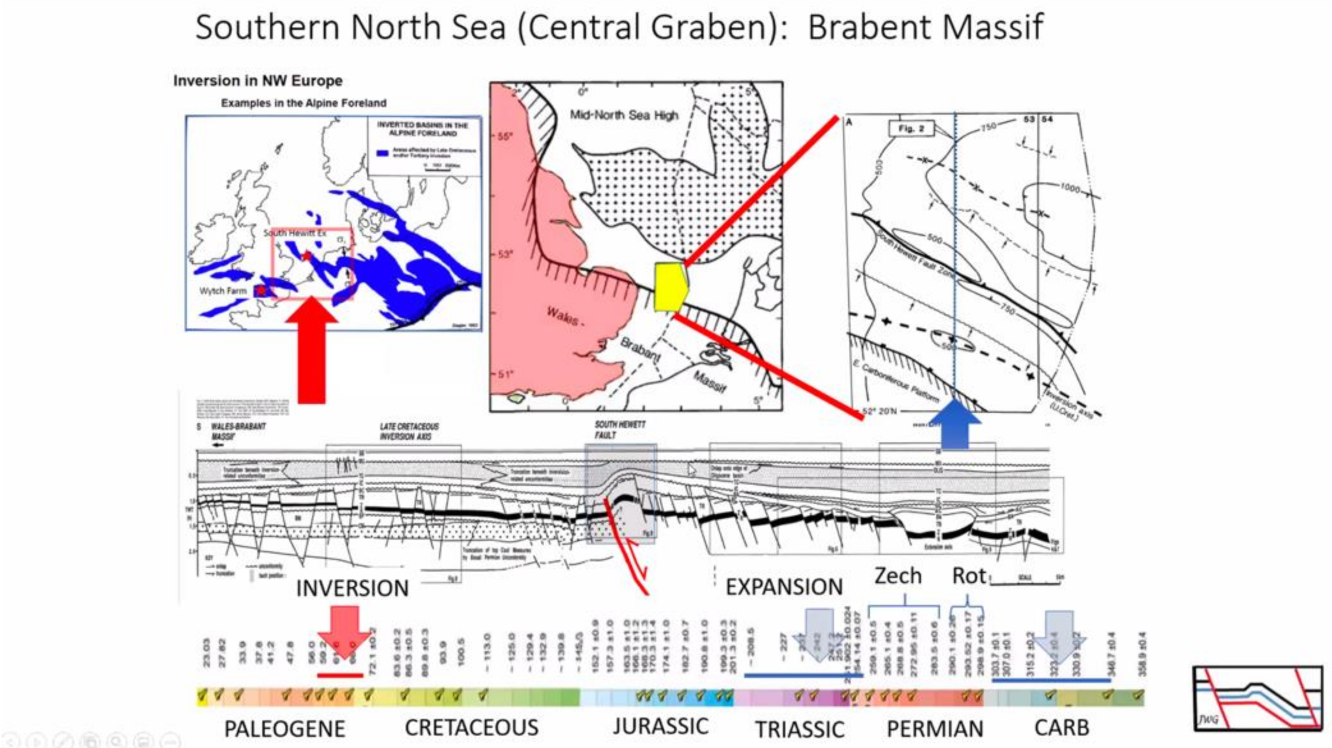
Alright, so that's basically the story here, popped on our STARSS diagram our TFA diagram. Again, just the notion that the convergence down south is driving the motion of the blocks internally during the development of the Rift. So we have the expansion here, growth of the Karoo basin during that period of time, at this point in time, this particular location for the Waterberg thrust, not the whole region, just the Waterberg thrust, we have this peculiar displacement relationship developed so that we get an initiation of inversion there that is then driven later on in the Cretaceous by the regional uplift. So I termed this syn-kinematic and allo-kinematic inversion. The allo-kinematic inversions is very common, it's around all sorts of Africa, the Senonian period was a time of inversion all over Africa. The Alpine inversion in Europe and the North Sea is superimposed on older features as well.



Jim Granath 50:16
So this is the same sort of thing, you can play with rates and say, you know, even a quarter typical fault, motion rates within the continent within the plates are about a half a centimeter a year when they're active. So even if you had a quarter of that a half of that being at differential rate, you can get 25 kilometers of displacement on the inversion, within just 10 million years. So there's no real issue about about rates.

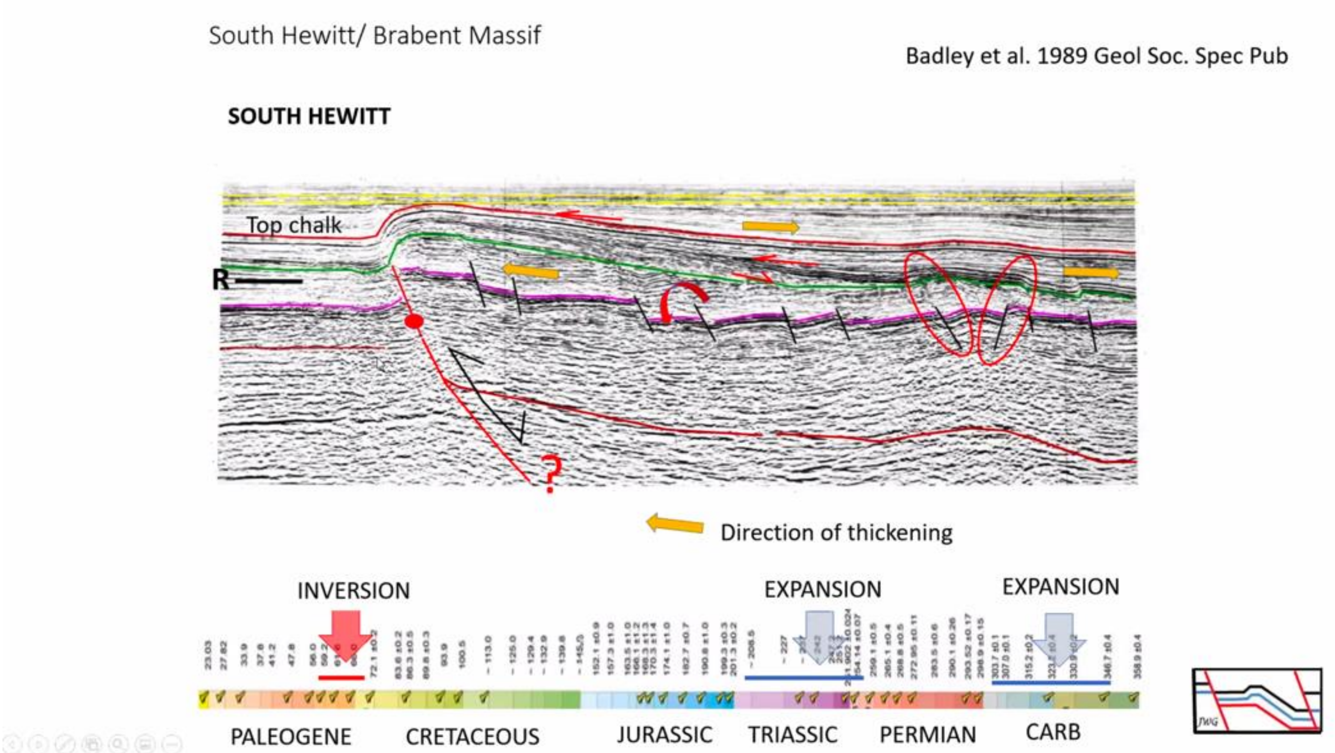


Jim Granath 50:56
A couple of North Sea examples, these are out of the literature.



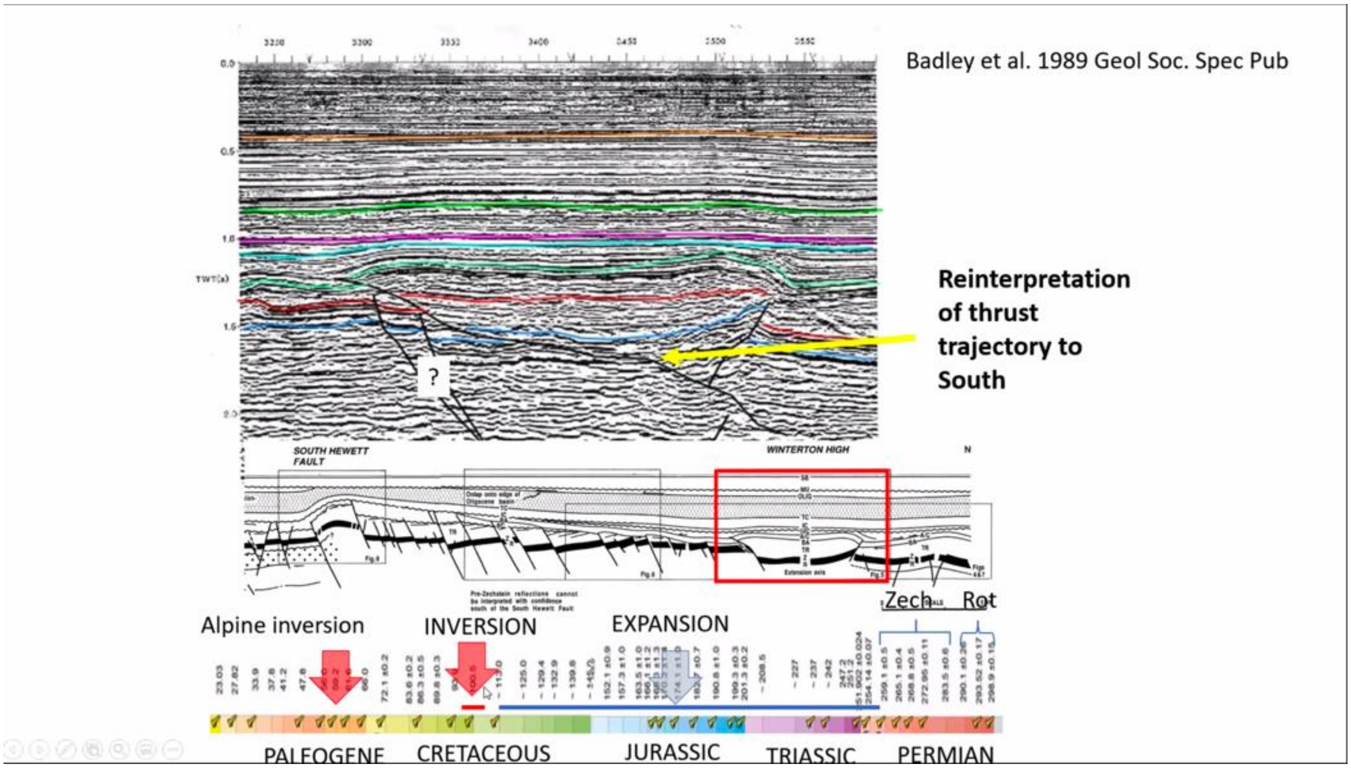
Jim Granath 51:01

Classic example of inversion was the Brabant Massif. This is a paper from the late 80s by Badley and company and it shows a lot of examples that we've been using courses with the inversion along the frontal structure of the Brabant uplift, or the South Hewitt uplift. Well, you can see that's driven at Cretaceous time. And Paleogene time, that's the Alpine inversion here. But if you look at some of these inversions, internal to it, for example, in here, you get a different answer.



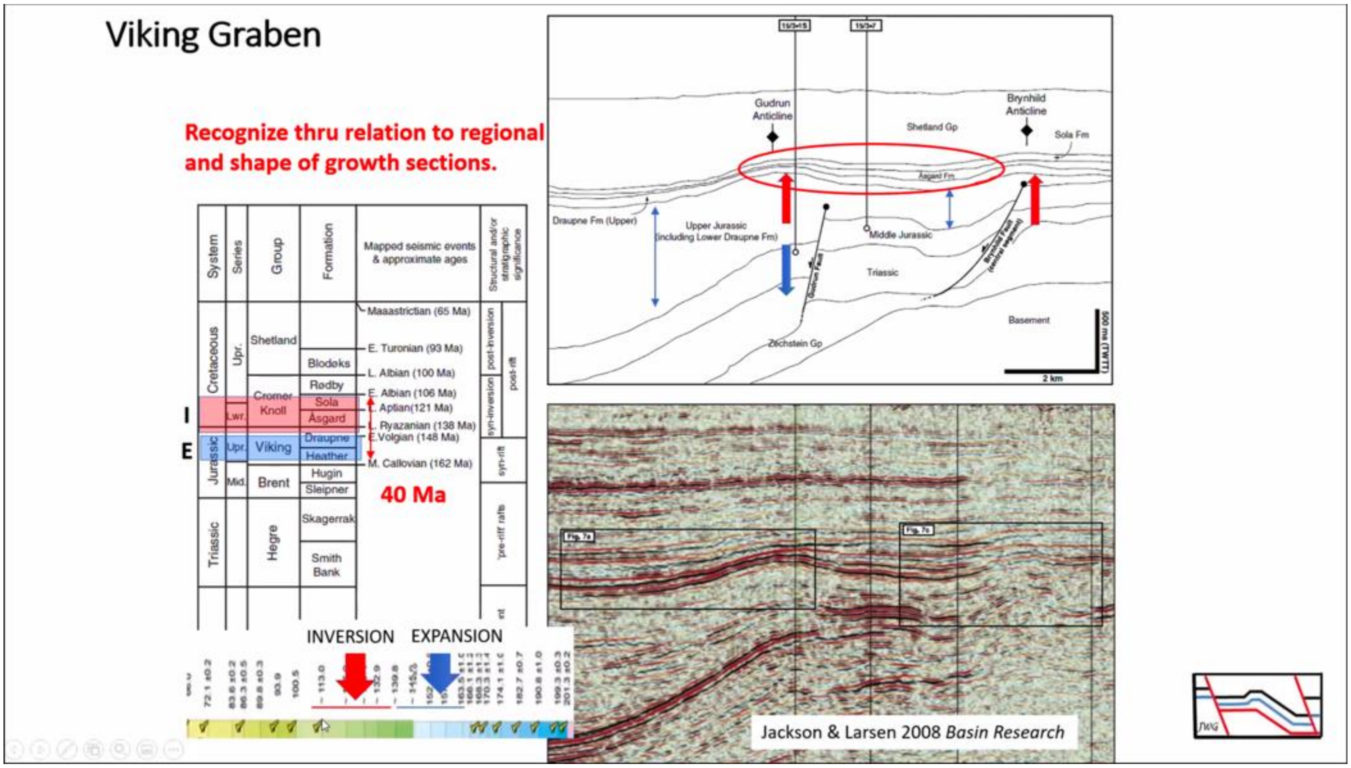
Jim Granath 51:35

Here's the seismic line of the whole thing, giving you the big Brabant uplit, or the big South-Hewitt uplift, you could see the Cretaceous thickening in the footwall here that tells you the age of that inversion, or at least the close of it. But if you go back and look at some of these other inverted features in here, they give you a different timing. They give you a timing at the green, which is, those are just for the South Hewitt.

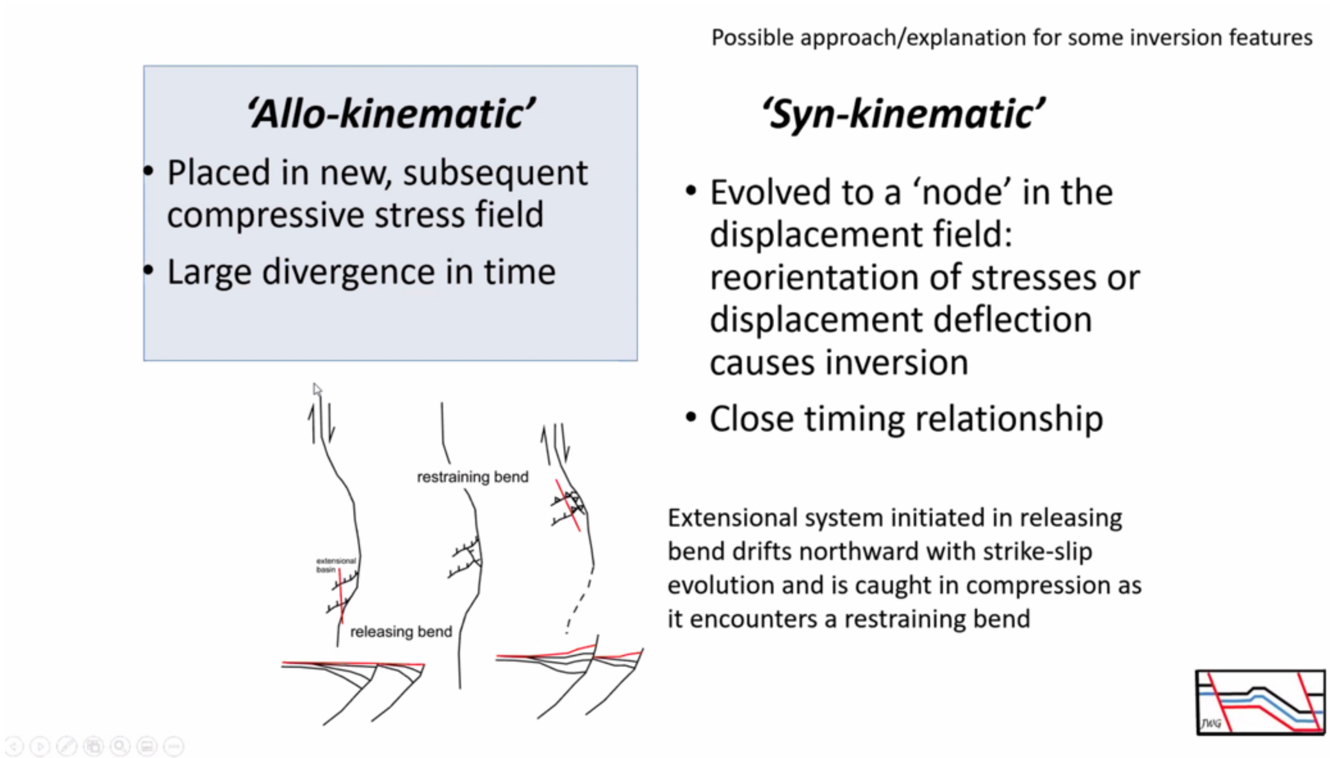


Jim Granath 52:04

If we go to this, which is somewhere deeper, older in the Cretaceous time. Here's a classic one. That's not a Badley's paper, this is the one I don't know if anybody's ever seen it, but they show it as a as a full Graben with both sides being inverted the same way. Well, I've interpreted it a little differently, it doesn't make much difference to the story. The important point is that the expansion section on the footwall on both sides is Cretaceous in age, not tertiary in age. Here's the Alpine event up here. So you've got expansion developing all during the period of time of this rift fill. And that covers a period from in places Permian and [inaudible] in time all the way up into the Cretaceous. And then you have this minor inversion every now and then in certain places in the middle part of the Cretaceous, and then that's overprinted by the much bigger Alpine inversion



Jim Granath 53:09
another one more recently. So here up in the Viking Graben, in Norwegian waters. We've got a similar sort of situation where you can see it in the seismic line and their line diagram, you can see the expansion section in the downed thrown side of the uplift. So these are being uplifted at the time of the deposition of this sediment. That's Cromer Knoll, basically Lower Cretaceous in age. So you've got development of the expansion faults earlier on during the Jurassic, the upper Jurassic, and then they're partially inverted almost immediately. Locally, and we never really see the overprinted Alpine section so the timeline ends up being something like this. With expansion, almost no delay whatsoever going right into inversion.



Jim Granath 54:28
So to close, Allo-kinematic versus Syn-kinematic. Allo- kinematic meaning some subsequent compressive, completely different tectonic environment drives the reversion in the stress on the fault. Syn-kinematic is one that naturally develops within the system itself and they are going to be characterized by a close timing relationship. Be interested in seeing ones that are developed right within the whole time, or even early on those rogue thrusts. And so in our classic structural styles here I've just drawn to a releasing bend in a restraining bend on a right lateral strike slip fault. So, on the west side, at the releasing bend, we develop our nice extensional structures, we can develop a syn-kinematic growth section developed on top of it. And that can be closed by a horizon that marks the closing of it. As the right side drifts to the north, eventually it's going to get into the restraining bend situation and those normal faults are going to get reversed. So we conceivably could see the same sort of thing happen here where we're in the same kinematic system, the same strike-slip system, there's no big change in the stress field. But we invert those structures, because they're now in a compressional environment simply because of the block relationships.

Jim Granath 56:10
Alright, so that's it.

Question & Answer session (selected)

Jim Granath 56:57
Ever drilled into the source rocks for the reservoirs that I have developed? Please comment on the fact that drilling source rock is not necessary or even useful in conventional oil and gas exploration development? Well yeah, if you look at the history, hell, I got into this industry in 1981. And it wasn't until the mid 1980s, that people really settled on what the source rocks were in the Gulf of Mexico. That tells you can have a wildly successful system for a long time without knowing where the oil is really coming from.

Ross 1:00:12
Hi, my name is Ross. I just had kind of a more layman question. This was an awesome presentation, by the way, you were super knowledgeable, and I really enjoyed all of it. My question is kind of more layman's terms. If you had to give the give the odds to us, you know, of, of the the likelihood of commercial quantities of oil and gas in the Kavango Basin? What do you think the odds are? I mean, just your opinion, not based on anything?

Jim Granath 1:01:13
I really don't have an opinion. Ross, I'm sorry. You know, in the old days, in the 1980s, when I was early in my oil and gas career with Conoco it became fashionable to try to quantify risk. Now, people were saying, geez, we only, we only hit on 10% of our wells, we ought to be able to do better. And then, you know, people pointed out that when these prospects get into oil and gas portfolios, they have wildly different data sets that support them. And they're really very little critical evaluation of how reliable those data sets are. So they developed a risk system that risked all the elements, it said, 'What do you know about the source?' and 'What do you know about the reservoir?' and 'What do you know about the the poro perm?' and 'What do you know about the trap?' and 'What do you know about the timing', and they assign probabilities between zero and one to those to develop what's called a geologic risk. This is usually before a well is drilled, and you don't know whether you're going to come up with hydrocarbons. So it's called the geologic risk. So by chance, these two wells have basically reduced the geologic risk to zero, we know there's hydrocarbons, and we know that they accumulate. And we know that there are rock properties that are amenable to that sort of thing. What we don't know, is on a big scale, the quantities or the movability, how much can be produced? So the things that really are commercial risk, we don't have a handle on. So there's no way to really estimate it.

Ross 1:02:59
Would you be able to elaborate maybe a little further, you talked about well, 6-2 and how it had oil that potentially could be producible? Is there any way that you can elaborate maybe more of your thoughts on that?

Jim Granath 1:03:23
Well, yeah, I mean, like I said, ordinarily, if you're drilling an exploration well, and you've got a good feeling on your system, you'll have gear at the rig so that you can go down and you can do what's

called a drill stem test. And that actually is a flow rate test. What they do is they try to produce the hydrocarbons for a period of time. And they measure that flow rate and measure the volumes that come out. And how much water, how much oil, how much gas? We know, we've got the light oils, we know we've got various kinds of gases, and we know we've got water. We just don't know how it'll move. Now that gear was not on location, because the wells weren't permitted by the government as prospect tests.So at the very beginning, all we were doing was trying to get those geologic factors under control. Is there oil, is there gas? Is there reservoir rock? What's the permeability? All those sorts of things, but we don't know how it flows. And so we have to go back and find that out. That's the next step. That's the step in trying to reduce the commerciality risk. So in an international project like this, it takes quite a while, it takes years to get to the whole point of being able to declare commerciality because you've got to do basically, site demonstrations, with those flow tests.

Jim Granath 1:04:59
And then you've got to decide, well, gee, if there's only 10 million barrels here, is it going to be worth producing it? So you got to know whether you get 20 barrels, 10 million barrels? a 100 barrels, a billion barrels, you know. So that's partly what the seismic program is all about, it's to try to decide how big the trap vessel, the vessel holding the oil can be. Are the two wells connected, who knows?! They may be spot locations. So you need the size of the vessel, you need how it will flow, what kind of hydrocarbons are coming out to estimate your volumes, then you go through the whole economic thing of what are we going to do with that? Truck it up to the coast? We're gonna burn it for power on location, what are you going to do? In other words, how to commercialize. All of all of that's down the road. So, you know, it's a marathon, not a sprint. It's not like going out into a farmer's field in Kansas. And there's a pumper Jack, two miles away. And you drill another well, and say 'Yeah, let's put it online. Well, it's not that big a financial risk to put a little project like that online in Kansas. Whereas, overseas, it's a gigantic financial risk. Because you've got to develop the whole infrastructure and everything and commit to the commerciality of that. Well, you better have the hydrocarbons there to pay for it. It takes a while.

Jim Granath 1:05:09
You bet. I don't think I stepped on anybody's toes. Those were completely general remarks. No,

Ross 1:06:49
You know, very informative, though.

Paul 1:07:17
Yes, I have two questions I've been trying to get answered. I guess. The first one is on Well, 6-1. TD was over 9000 feet compared to like, 6-2, which was like 7000 feet. So do you know from the logs that you have, was most of it the thickening Karoo, was it a combination of Karoo and something else?

Jim Granath 1:07:51
I would refer you to the original release on 6-2. I don't know the figures on that. I know that some Karoo and some Pre-Karoo in both wells. One of the things that I was trying to point out was, as long as we're in the fold belt here, it doesn't really matter what's in the pre-Karoo, because it's going to be whatever

lithologies and whatever rocks are in the the fold belt and that's going to be a mixture of stuff that's off the Congo Craton versus stuff that's in the Foreland basin before it gets gobbled up into the thrust belt. So it's all going to be kind of scrambled up and we're gonna be in different structural positions. You know, it's kind of like driving through Denver on i 25. And coming up with a map of the whole city.

Jim Granath 1:09:10
Namcor has allowed us to release that basic stuff about 6-2. 6-1 is still under study.

Paul 1:09:22
One other question on the seismic shoot. There were plans that you all publicly released that there was potential for additional seismic. Was any additional seismic shot based on some of the realtime [inaudible] data that you're seeing in the field, that you might have wanted to add a line, or create a fire break and put a line?

Jim Granath 1:09:49
It's always been in the plan to shoot more seismic. But see, these things all have to be permitted by the government. The exact position of the lines has to be laid out, and an environmental impact statement has to be done. And so various parts of the government have to sign off on that. Oddly enough, even the water people have to sign off on seismic data even though there's no relevance between the two. So the first phase, a budget was built, the first phase was laid out. To get an idea of the whole overview picture, the 450 Kilometer sort of spans all of those deep holes. And it was drawn out, and it was mostly along roads, and it was permitted, and then it was shot. Well, the government came back and said, Gee, while you're out there, we had to smooth along little shoulders along roads and stuff, they said, why don't you do some firebreaks for us. And ReconAfrica replied, Well, sure, if you let us shoot along them, and they said, Okay. When I say shoot, I mean, just do the weight drop [inaudible]. And so now, they haven't been shot, the brakes, I think have been, or they will be cut. And there'll be left behind of course, just because that's their purpose as firebreaks. And then that data will go into the processing shop and go through another round. Well, in the meantime, we're also thinking about where additional lines can be shot around the wells or along other roads or whatever. People are people are thinking about that right now. And it'll have to go through the whole process the same way a new well have to be located, and permitted, and it just doesn't happen in a day.

Paul 1:11:52
Yeah. I didn't know how much discretion recon had, relative to some of that additional seismic.

Jim Granath 1:12:01
Yeah, it's, it's very little, to be honest, I mean, you know, we can nominate things. And for the most part, we nominate them with knowledge of what the impact would be. And I guess the biggest environmental concern is that the weight drop, you know, just drops a big weight on the ground and creates a thud. There's not much environmental impact or damage to people or the ground, we just have to make a flat spot to drop it on. And that's why we stuck the roads. In a lot of cases we made little shoulders to the roads, so we improved the roads. But then when you get a cross, when you want to cross-country, you've got to make your own path. And that's part of the reason the weight drop system was used, because it's very narrow. We don't need the whole road width to take place, you can basically go work

your way through the bush, because it's a John Deere tractor that's outfitted so it's what, two, two and a half, three meters wide, that's all. It's like driving a truck through the bush, but then it drops the weight, and the thud creates the seismic wave. There's some concern about that effect on wildlife. We've been keeping track of wildlife, and [inaudible] with rangers and stuff. There's a big, big ESG plan. Oh, that was all mentioned, there's wildlife monitoring involved in our program. You know, it's just the right thing to do.

Paul 1:13:57
The basement color map that's out there, the well locations of 6-2 and 6-2 seem to be in a deeper area

Jim Granath 1:15:01
Well, that was the original thought. The original thought was to drill one a little bit more out in the basement.

Paul 1:15:08
I guess I'm a little mystified that, I know you say it's in the Graben and stuff, but I would have thought 6-1 would've picked up source rock

Jim Granath 1:15:23
If it were the simple case that we that we didn't get underneath the Karoo, which was the intention, to get into the deeper part of the basin. But as it is, it was still high. That that colored model tells us where the crystalline basement is. It does not tell us what's in between. Or how thick that is. And that's sort of wher the modeling comes in. And models you know, in science, anybody who's been watching weather models on hurricane tracks or models on pandemic results, models are made to be wrong. They're not predictions, they're intended to be guides to thinking, and possibilities.

Paul 1:16:14
I guess the only thing I was thinking about was, you know, since you know, the location of 6-2 and 6-1 are in basically blue areas, and you got a lot of green, yellow, orange, red scattered around adjacent to it, which means that in theory, at least the basement is shallower than the two well locations, which probably means, you know, your shallower sections are probably thinner. I would imagine.

Jim Granath 1:16:45
We would call these high blocks, but they may not be the highest blocks. They might be high relative to the deepest parts of the Grabens. But that's why people are going do seismic data, and it'll be interpreted. ,

Paul 1:17:00
You might have higher structures and stuff, but you may have less reservoir rock because you're at a higher location and either wasn't deposited?

Jim Granath 1:17:10
Maybe it's an inversion location, like all my like my models in the second part of this presentation suggest? We just don't know that yet. But the play concept has held up pretty well. I mean, just the rift

fill is dimensionalized a little differently, but that's why we've done the on the work of going out and trying to calibrate the models with real data.

Boris 1:18:03
Hi, Jim. I appreciate doing this kind of talk with us. It's super informative. I was just hoping in kind of your terms of your you've seen a lot of these projects come to life and whatnot, how long would it take for them to start initiate doing DST testing on the reservoir and things to see if it's economic or whatnot? So like, what would be a relative scale or a timescale for that?

Jim Granath 1:18:32
It depends on when the company decides it fits in the plans. I'm more of a seismic person and a seismic interpreter. So I'm not a definitive drilling guy. But my understanding is that the rig we have there could do that kind of a project. It would have to go back to location and have to re-enter the well, and all that sort of thing. It can be done with a smaller rig, called a workover rig. But that would be introducing another one of those into the country. So there's just lots of technicalities that are related to it. And like I said, I can't speak for the company's plans. They're all in formulation. You know, you start talking about specific plans, they turn into promises and....

Jim Granath 1:19:36
Well, I mean, you'd have to go through the permitting process again, we got to go to Namcor knows that we probably want to do that. But it'd have to go through the whole, every step of the process has to go through the regulatory scrutiny.

Boris 1:19:55
Beautiful

Jim Granath 1:19:55
and so I don't know what that timeframe is. That's why I hedge.

Boris 1:20:02
I love reservoir geology, that's kind of a big interest of mine. So it's not just this specific project that, uh, that you're exploring, but just in general, I love reservoir, engineering and whatnot. So that was my keen interest. So, alright, I appreciate you answering the question.

Jim Granath 1:20:24
You bet. I know, it wasn't much of a answer. It basically says, I don't know.

Boris 1:20:28
And sometimes that's good enough.

Jim Granath 1:20:31
Well, it's, um, and I gotta be honest with you. I mean, I don't know everything that's going on in the company, because I'm not in the management. An independent director has to be at arm's length. And so I have to be careful I can speak in this sort of a forum, in generalities that would be applicable to any project. That's about all I can do. Just to control expectations.

Boris 1:21:03
Beautiful. I look forward to the seismic data when it comes out. Just tell me what you think of it. That's exciting.

Jim Granath 1:21:10
I'm dying to see what they look like