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SPE Workshop: European Formation Damage

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Budapest, Hungary



Novel Proppant Systems for Sand Control
and Enhanced Performance of Cased Hole
Frac & Pack Injectors and Producers

Daryl Johnson

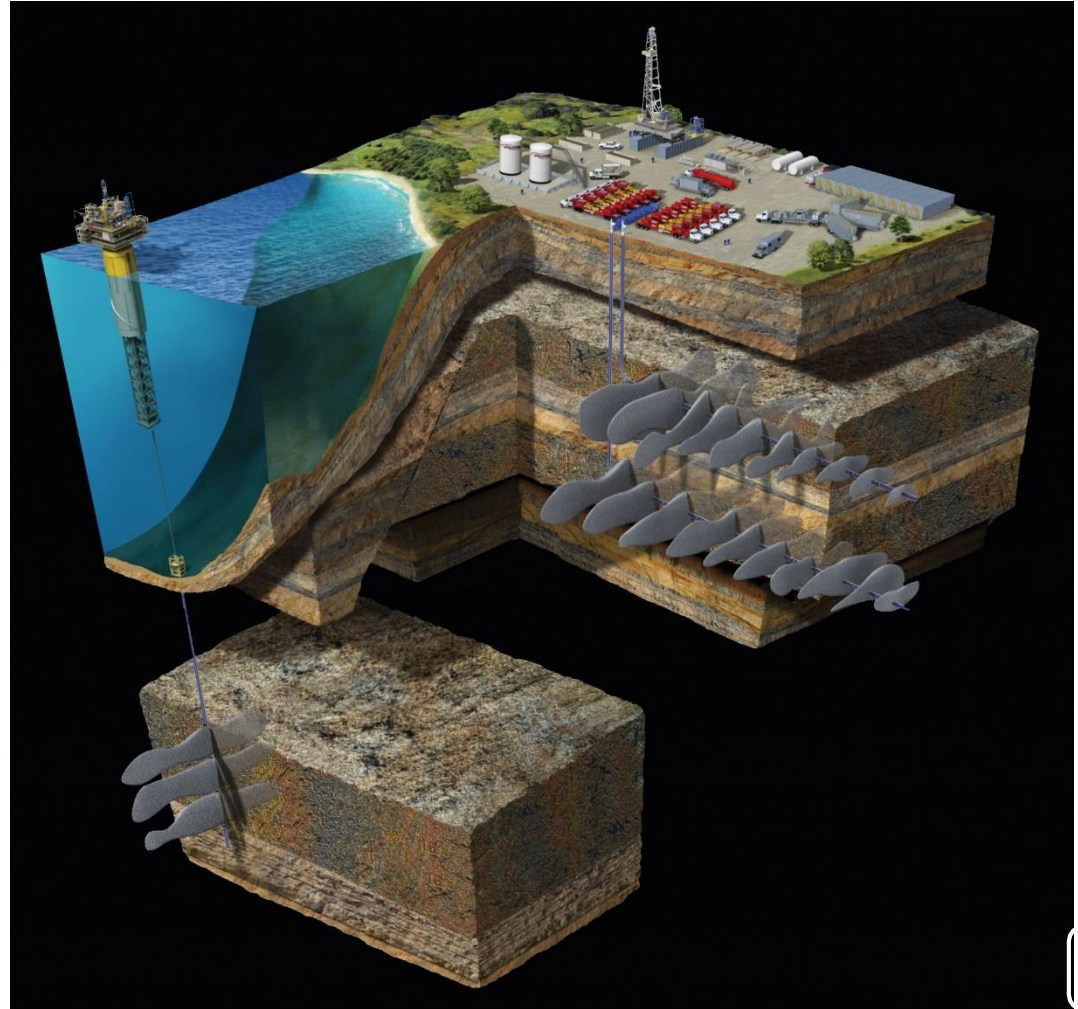
CARBO Ceramics And Technologies

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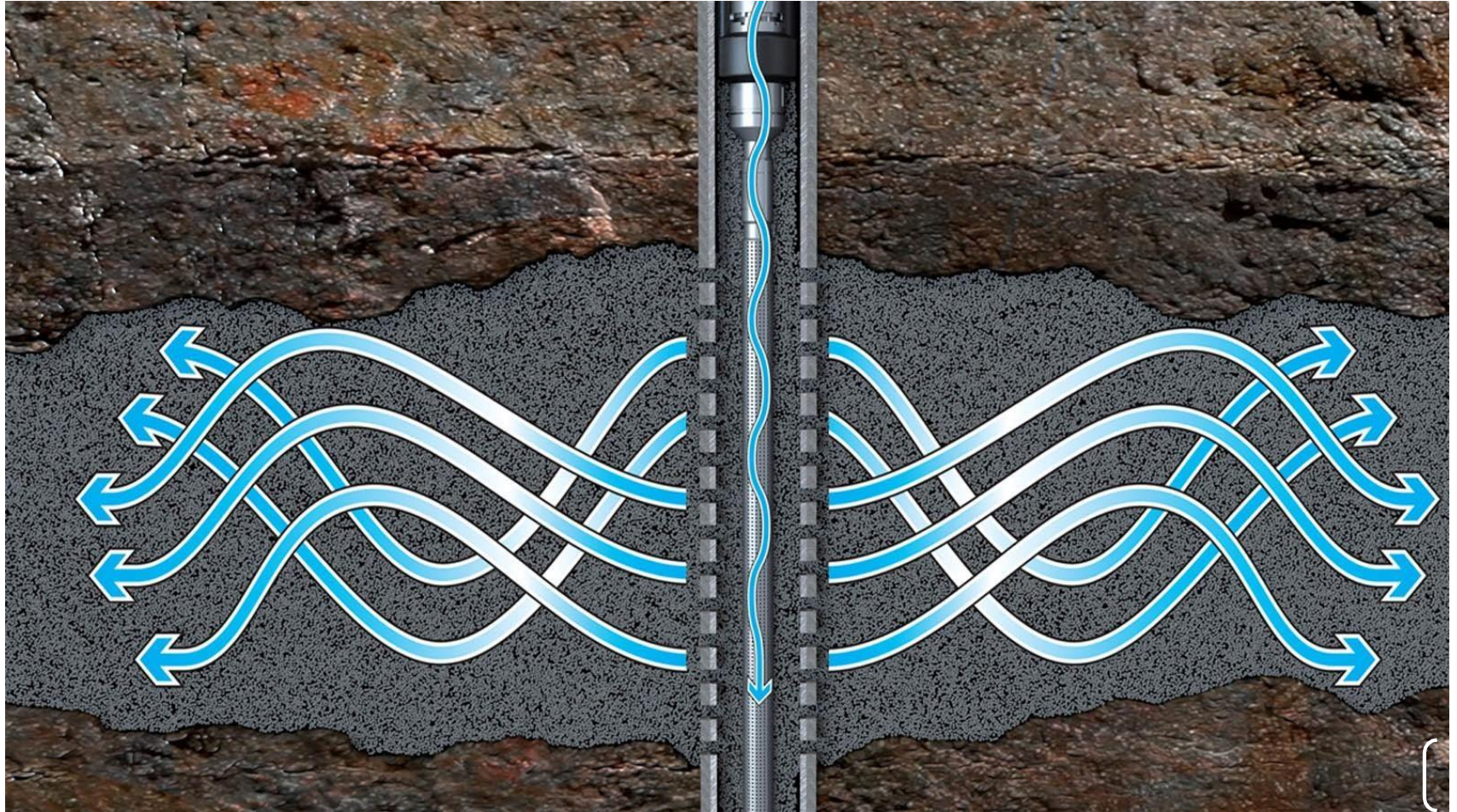


The Challenge: Stimulation of High Rate CHFP Injection & Production Wells Requiring Sand Control

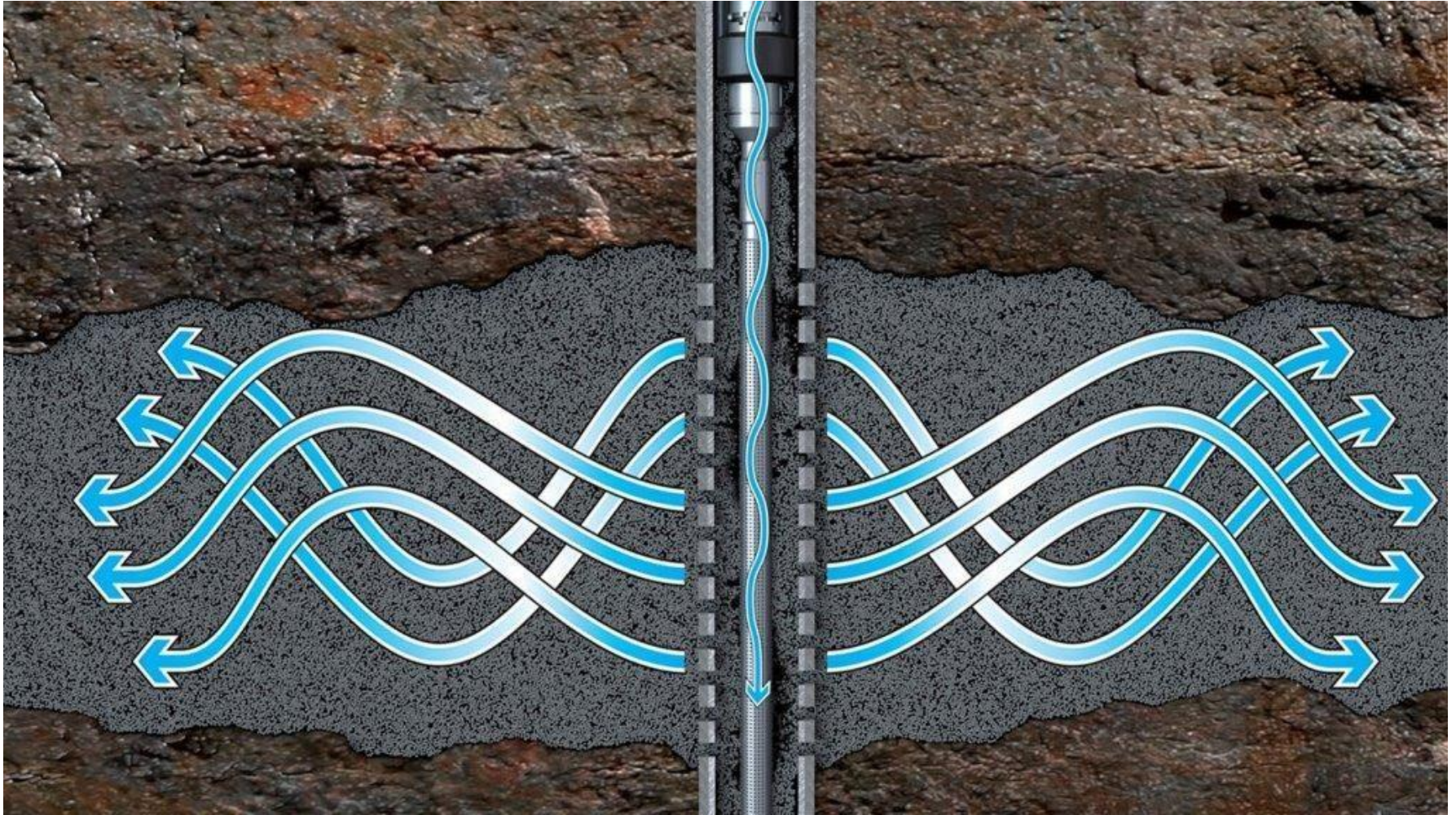
- 1) *Provide a robust, high permeability, proppant stimulation system that can sustain ultra-high water injection or production rates of 30K-70K bpd, withstand frequent cycling and provide secondary sand control in the annulus*
- 2) *System must be compatible with new production chemical technologies*
- 3) *Provide a cost effective sand control option for high rate and very low rate producing wells*



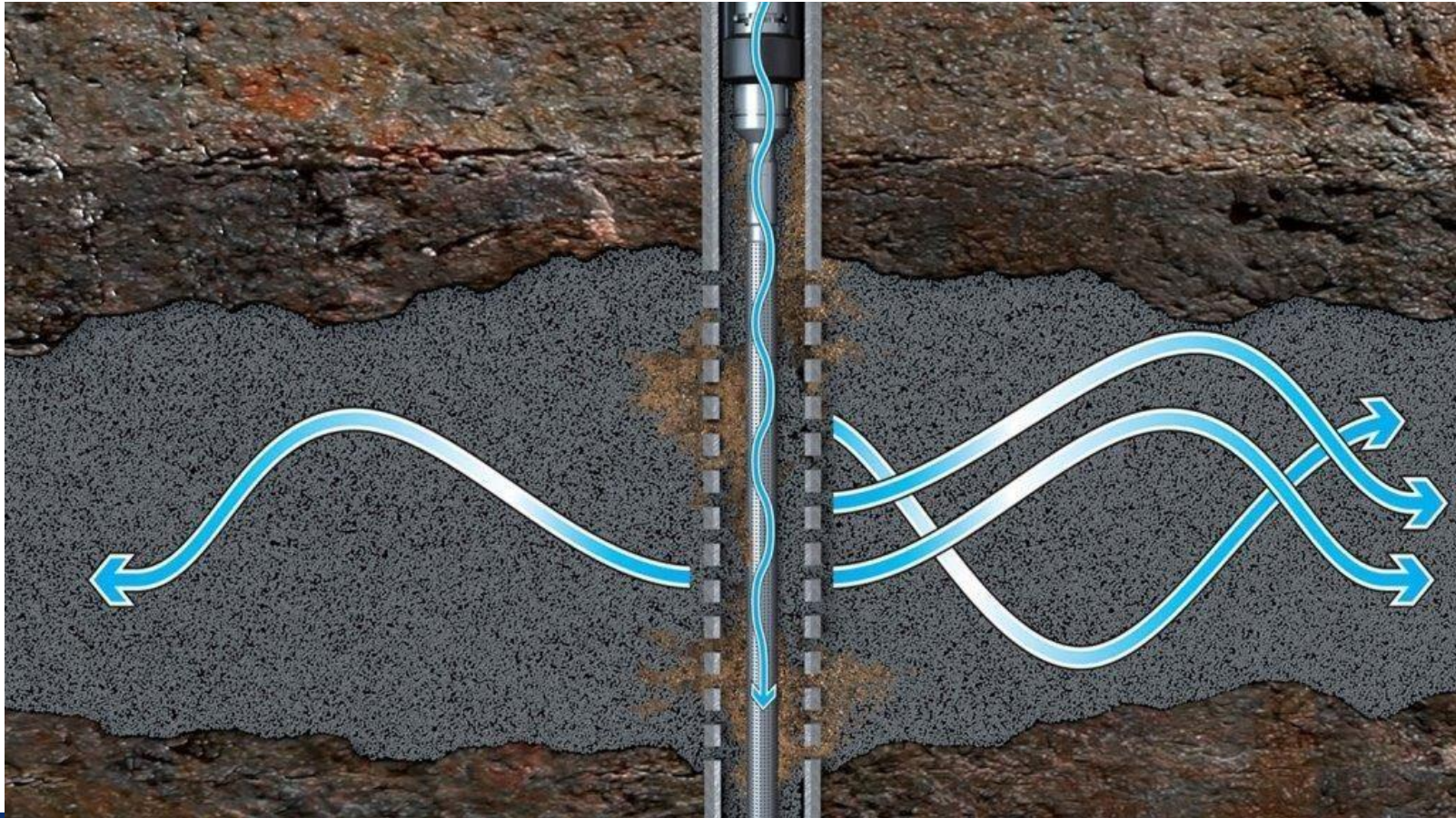
CHFP Injector – Initial Injection



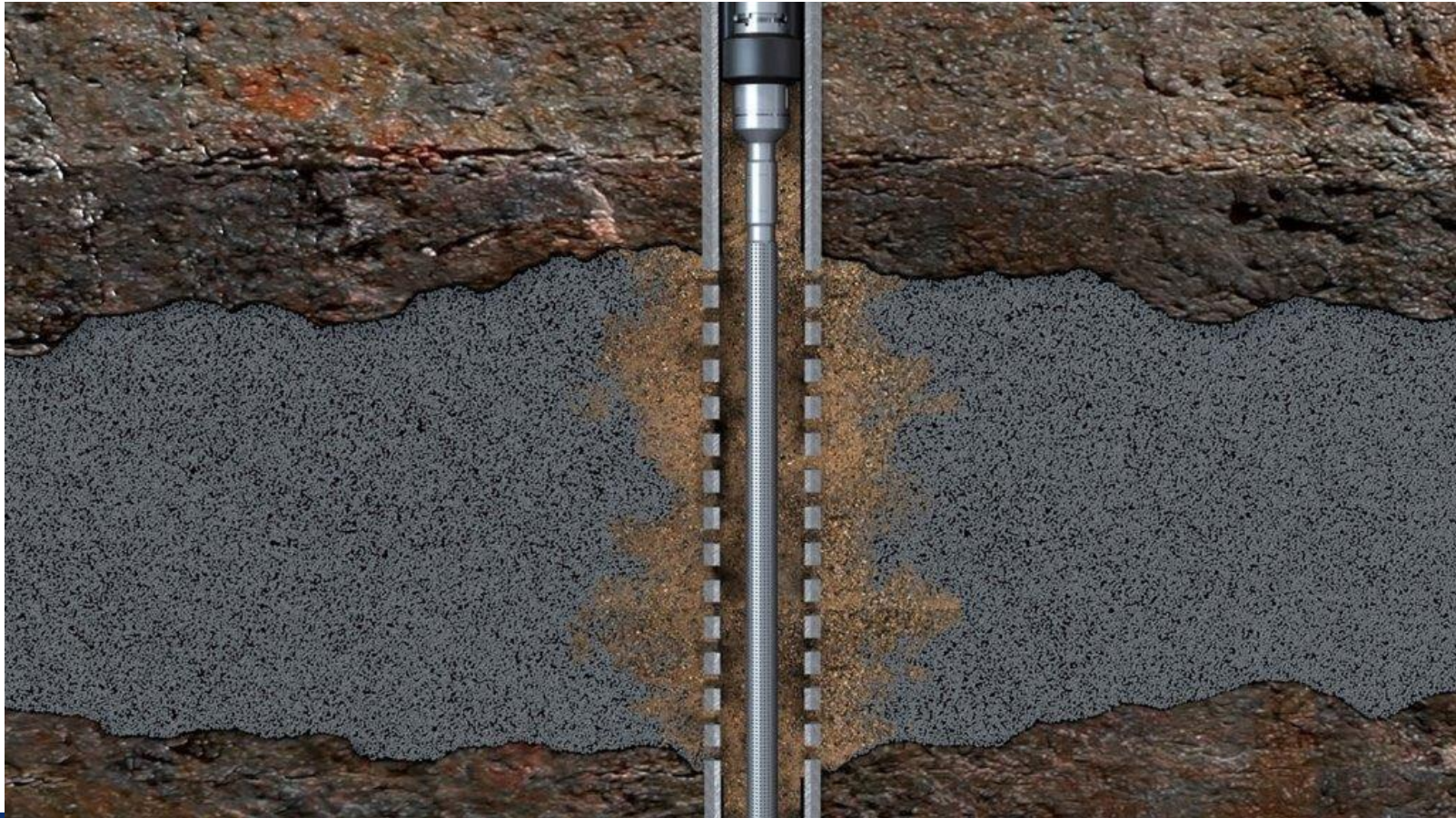
CHFP Injector – Voids in Annular Pack Starting



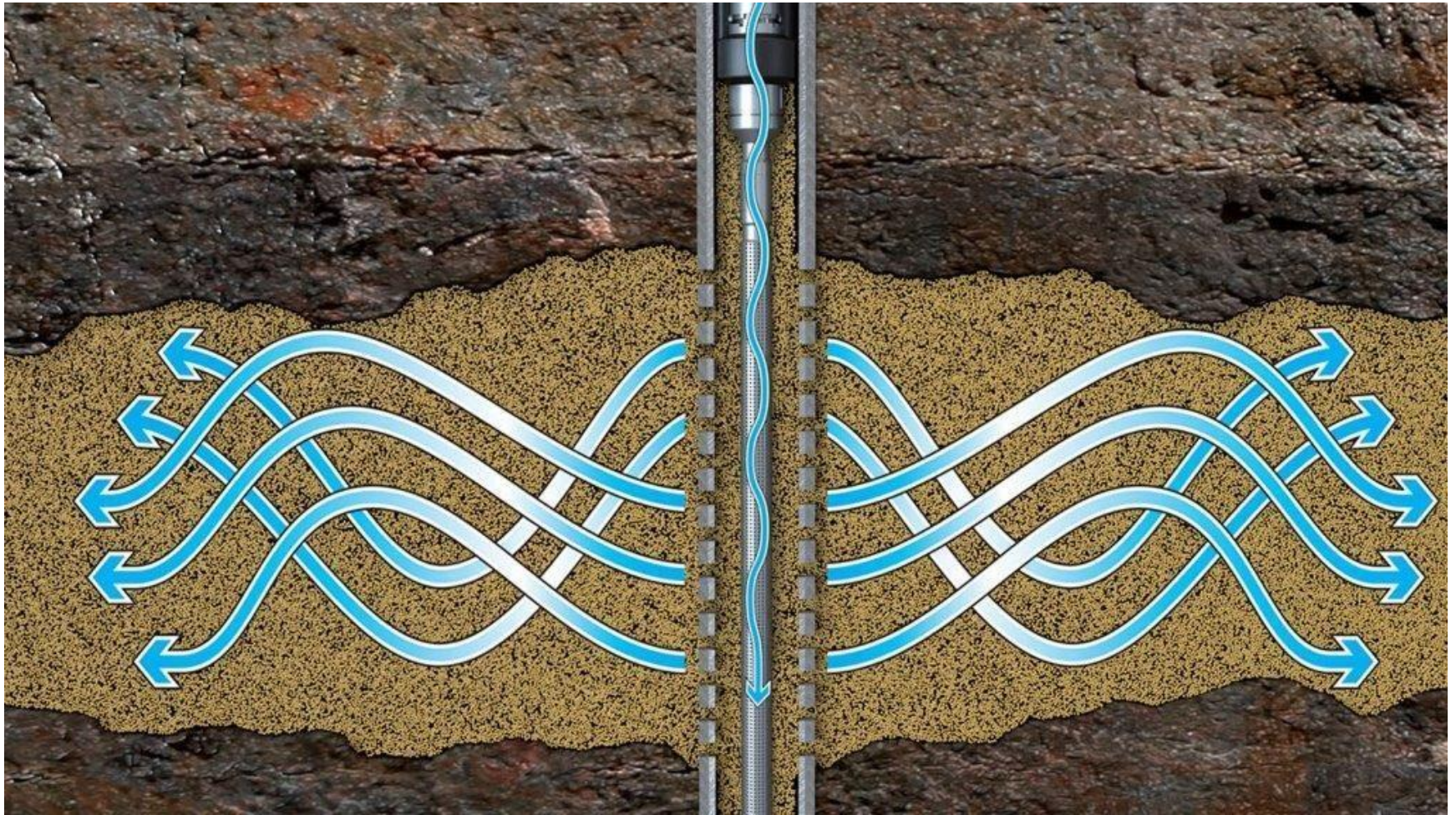
CHFP Injector – Injection Reduced, Fines Invade Pack



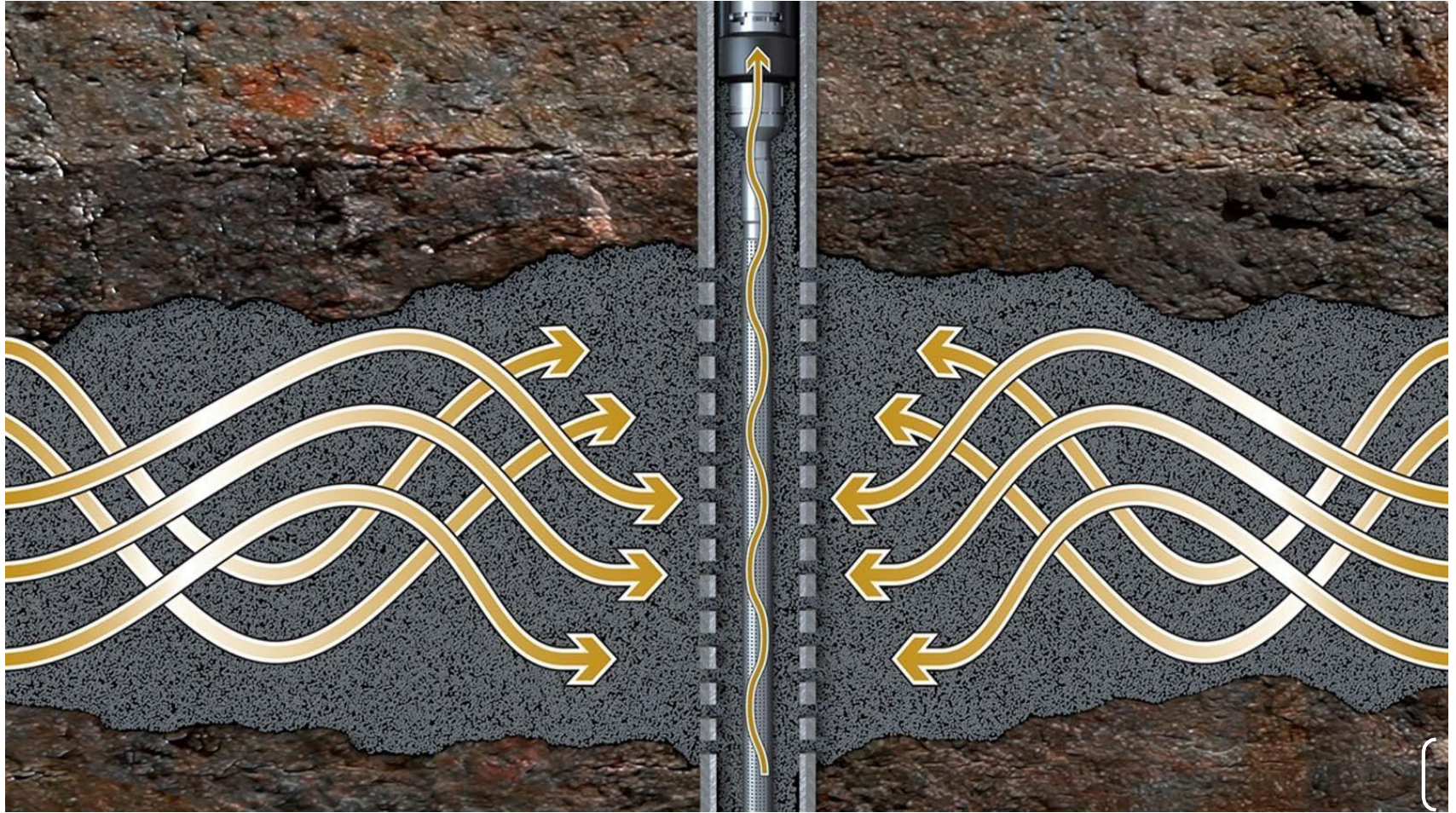
CHFP Injector – Injection Reduced To



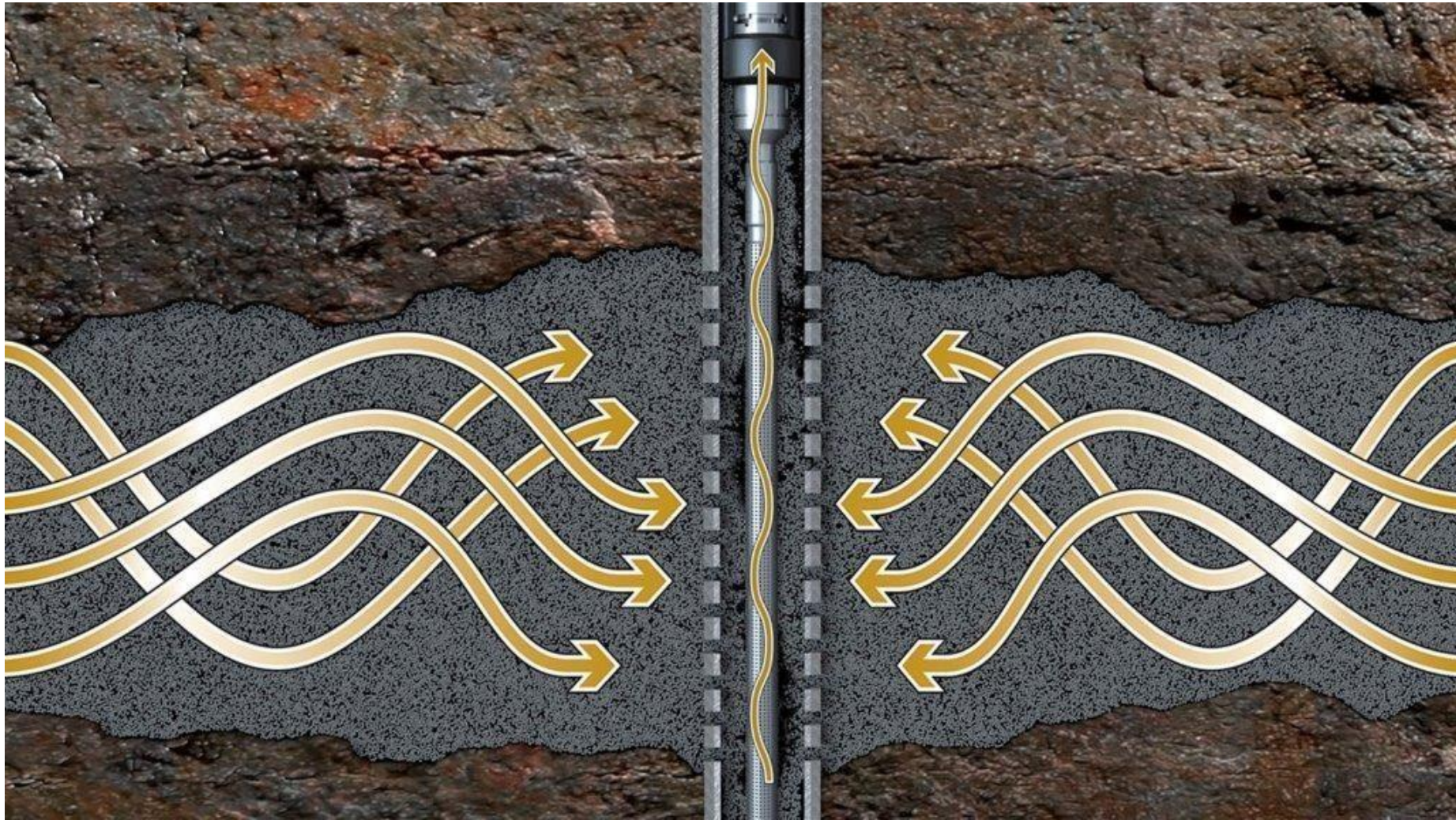
CHFP Injector Goal – Bonded Packs Locked In Place



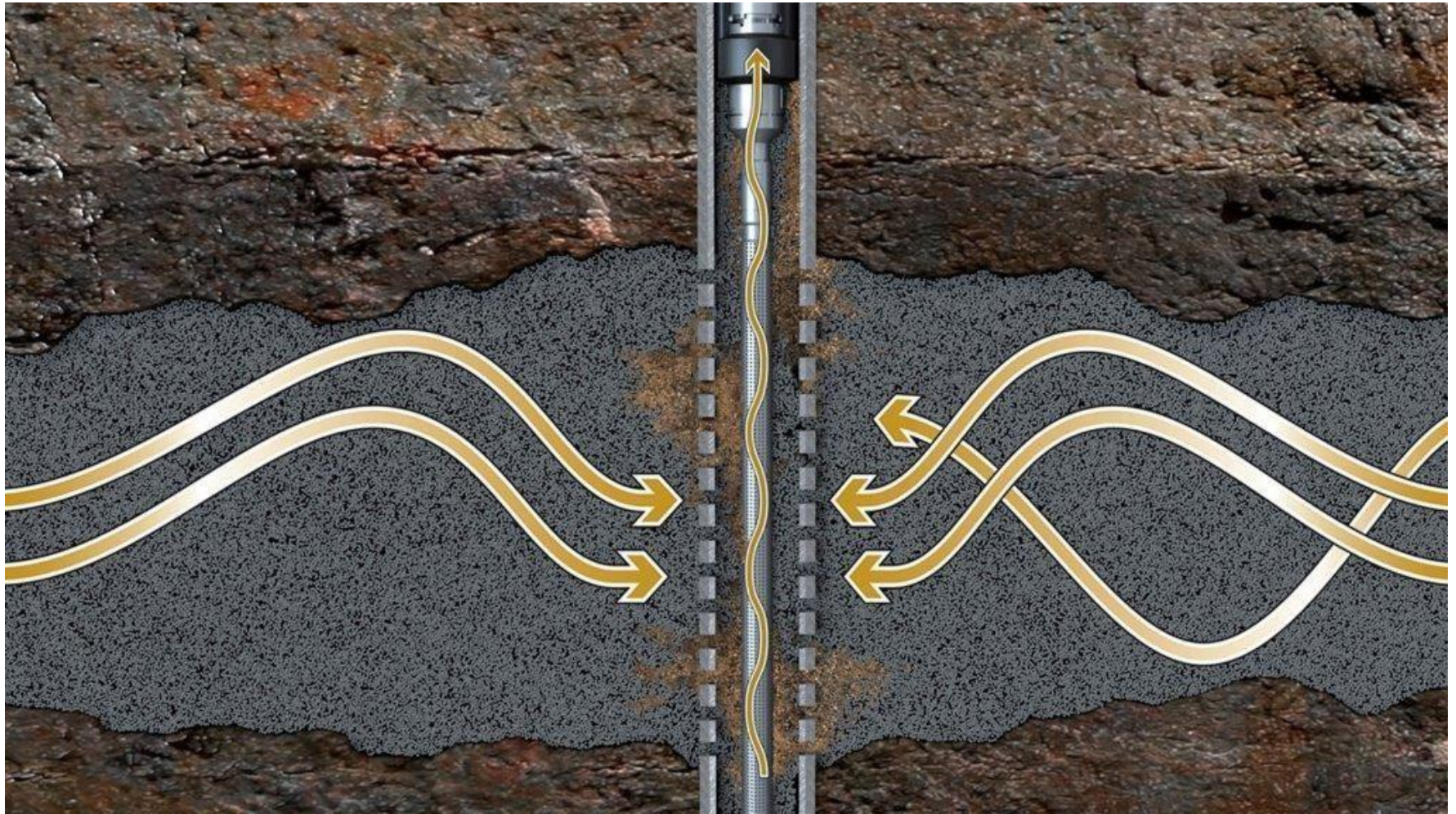
CHFP Producer – Initial Completion & Production



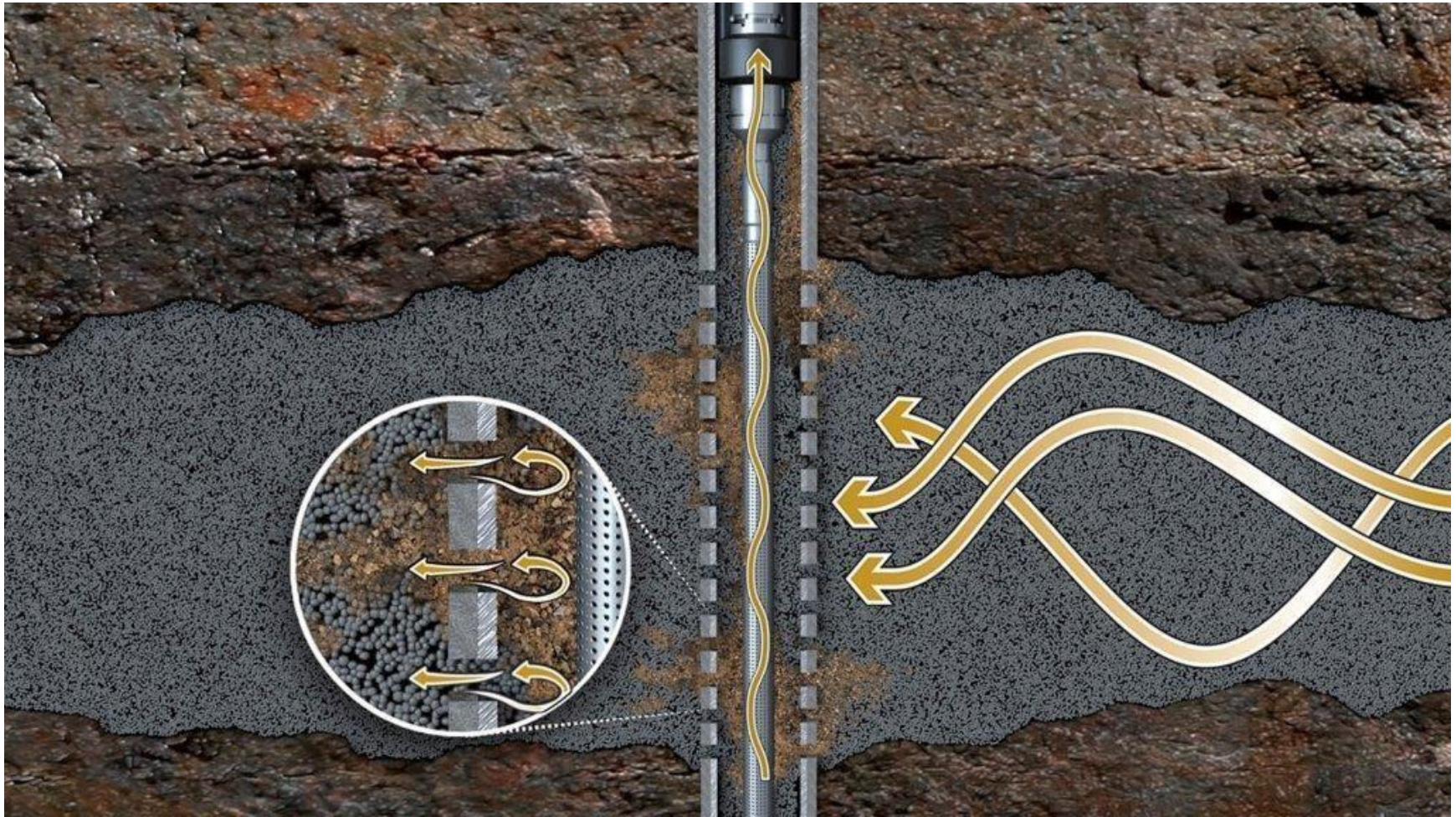
CHFP Producer – Voids Started



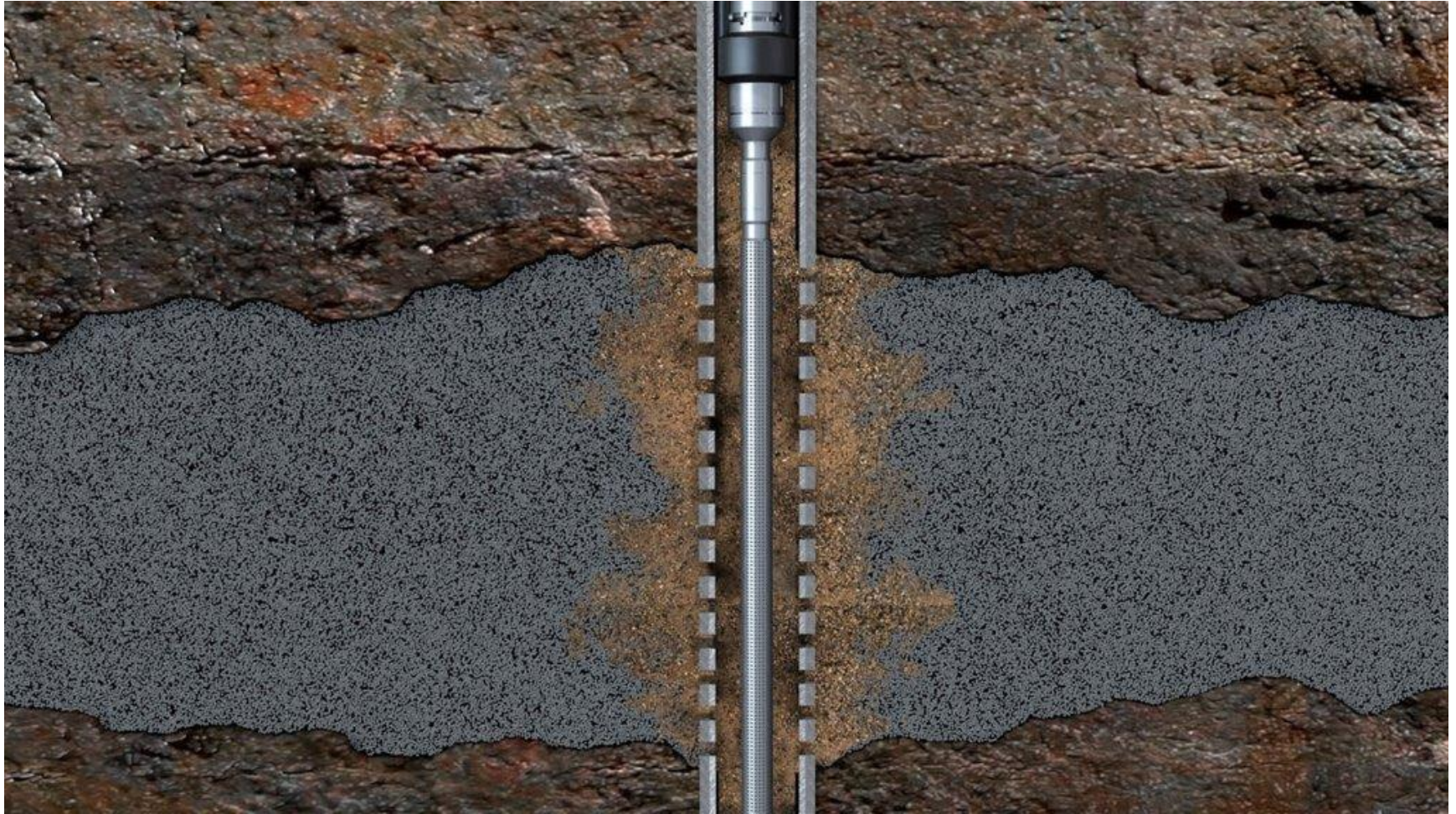
CHFP Producer – Fines Invasion of Voids



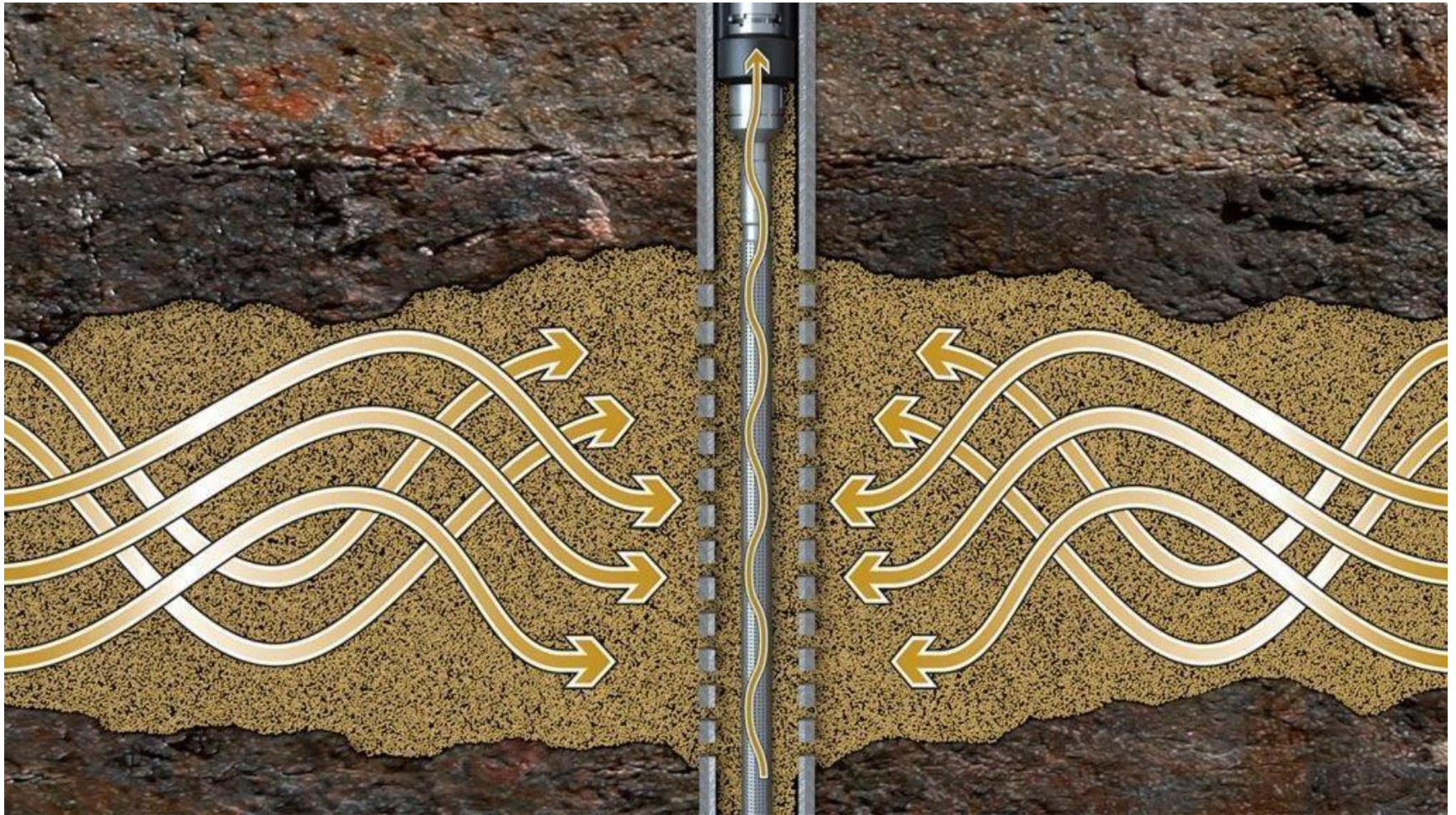
CHFP Producer – Annular Vortex Creates Larger Voids



CHFP Producer – Production Dramatically Reduced



CHFP Producer Goal – Prop Packs Locked in Place



Proppant System Qualification Testing, Phase 1

- **12 Different lab and field test protocols based on 4 key elements** required to meet ultra-high rate deepwater injector qualification
 - **Resistance to fluid flow; Ease of deployment; Treatment longevity & Product limitations or incompatibilities**
- **30 Different products screened** using the above testing criteria
 - **29 failed** to make it through the testing regimen
- Product #30 Passed All Lab and Field requirements
 - Extensive lab testing for mechanical properties, curing time, prop pack bond strength, fluid compatibility, long term conductivity, single perf tunnel high flux flow through a set pack, stress and temperature cycling
 - **250 cycle test on cured proppant pack plugs: 10kpsi -18kpsi & temperatures of 50°F - 250°F**
 - **Yard tests run** with frac pumps to pump proppant slurry through bends in treating line & crossover tools to check for coating erosion and insure prop pack strength
 - **8ppa/32bpm**
 - 3 Test Facility Wells
 - **Injection up to 30K bwpd for 3 weeks**
 - **Worst case scenario** as there was no formation to support the annular pack
 - **Packs remained consolidated with no proppant production**
 - Qualified Neutron tools for annular prop pack evaluation

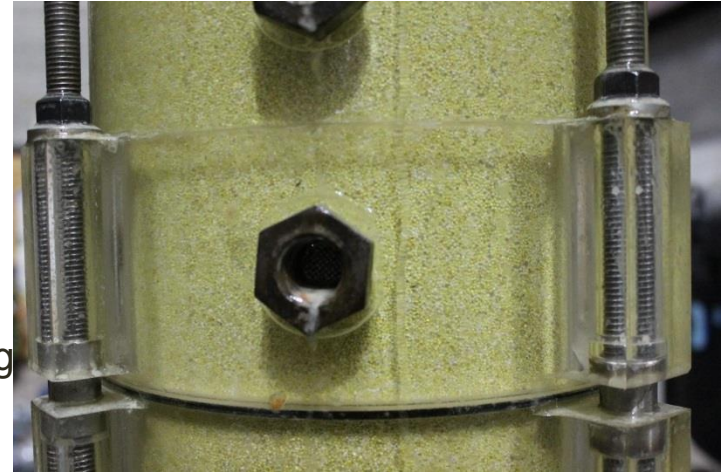


Injection Well Test Facility



Fully Packed
CHGP Assembly:
Plexiglass Casing

Close-up of
Packed Casing
& Perfs



Close-up of Set
Proppant Pack with
Plexiglass
“Casing” removed



Proppant System Qualification Testing, Phase 2

- **2 Field Deployment trials for Multi-Zone CHFP/GP tool operation**
 - No tool interference or incompatibility by proppant or system
- **1 Long term injection trial** with land well configured as the offshore injector
- **Stim boat “yard tests”** performed pumping the actual fluid system & resin-coated proppant through the treating lines & mock service tools
 - **8ppa & 32 bpm**
 - **Slurry samples caught and evaluated** for proppant pack strength



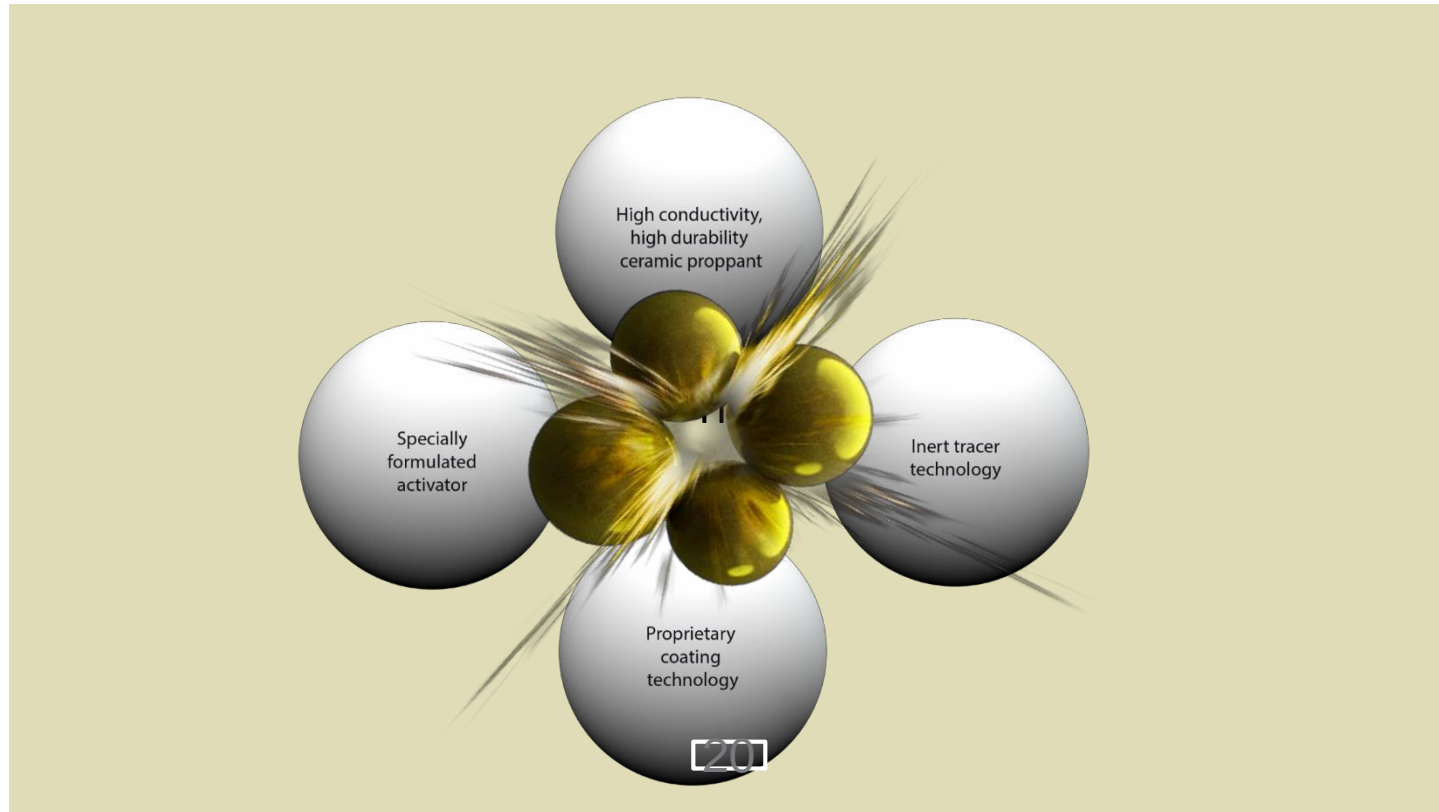
The Result: *“If at first you don’t succeed, keep trying”*

- The **30th** product tested worked!
- A unique solution for prop pack stimulation and annular consolidation for injectors and producers
- Creates a highly conductive and permanent proppant pack in non-compressive environments
- Maintains frac and annular pack connection
- Prevents propped pack rearrangement
- Bonded pack minimizes proppant embedment
- Coating and activator system applicable to all ceramic proppants
- AND Allows proppant pack quality verification of both the frac and annulus for the life of the well



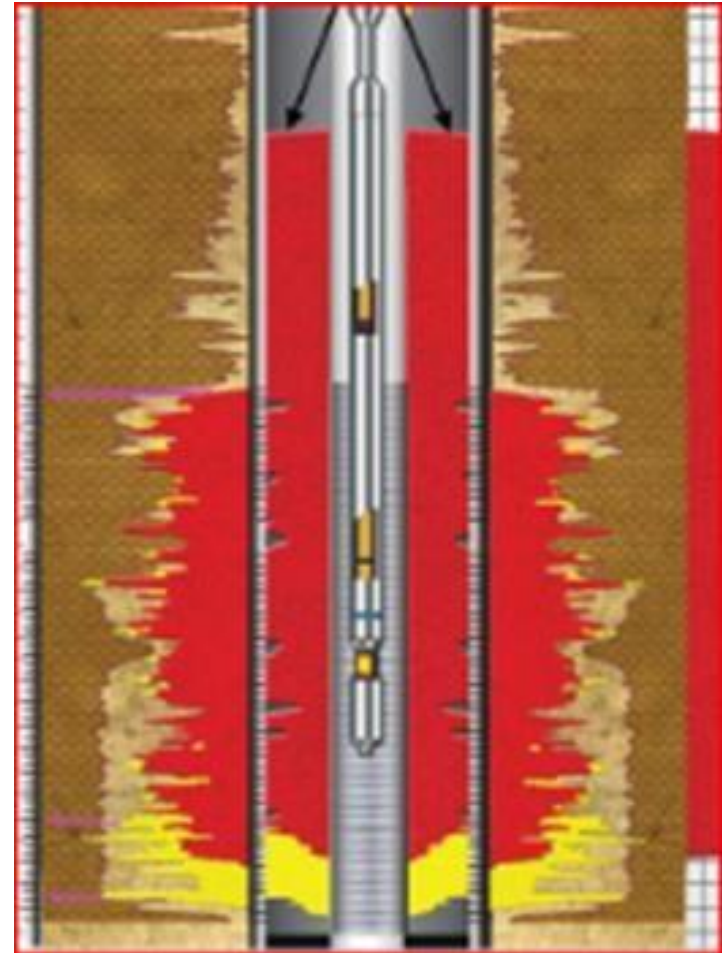
Proppant pack formed with zero closure stress

The Solution: Integrate Four Advanced Technologies



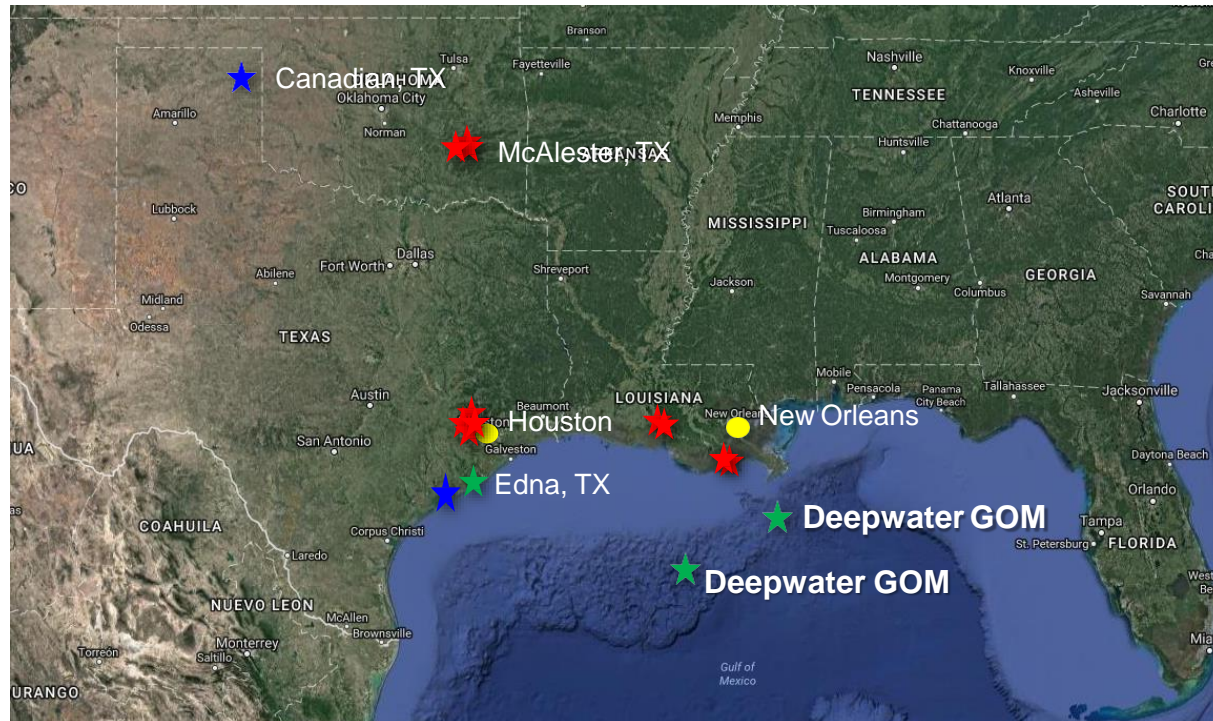
Inert Tracer for External & Internal Pack Evaluation

- Non-Radioactive Inert Tracer incorporated into proppant grains during manufacturing
- Formation Evaluation Neutron Porosity logging tools used to evaluate near & far field
- Allows the *proprietary* evaluation of pack integrity, near wellbore connectivity and propped pack height throughout the life of the well



Field Testing & GOM Deepwater Injector Map

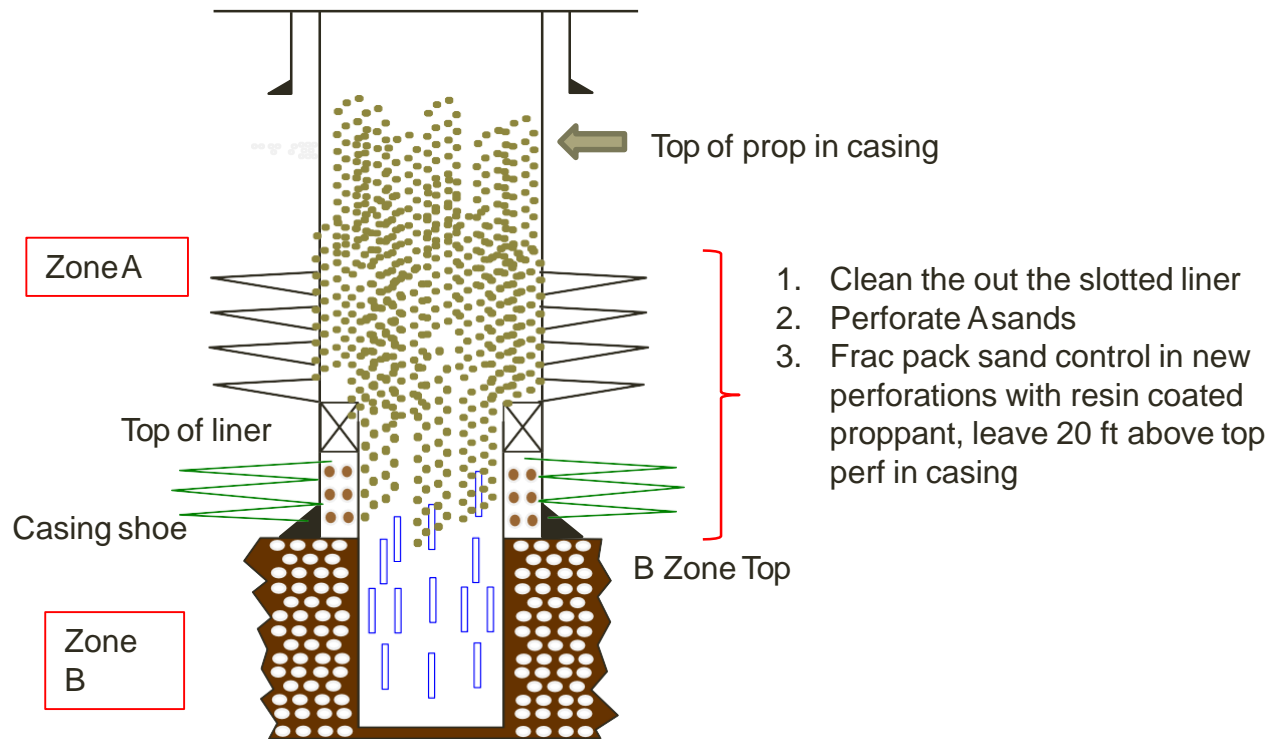
- ★ Yard Test
- ★ Field Test
- ★ Injection Well



CHFP Injector Results:

- 3 Test facility wells, 2 operational field trial wells, one land implementation injector & 2 successful commercial deepwater injectors
 - Test facility & land based injector had injection rates of up to 30K bwpd
 - Land injector injectivity vs delta P increased over time
 - Final injectivity index was 68 bwpd/psi with resin coated 16/30 ceramic proppant
 - Injection test lasted 5 months; 1.5 million bbl of water injected
 - Land injector logged over 10x without any annular pack or propped frac changes
- Deepwater GOM injection well rates up to 50K bwpd
 - One well on for over a year; one well tested & waiting to be put on-line
 - Both have resin coated 16/20 lightweight resin-coated proppant
- All wells had injection rates greater than frac pressure

Producer Recompletion Proposal for Sand Control



Production Index for 5 1/2" and 7 5/8" Casing

**Casing
Size**

Prop

**80 ft
Prop Pack**

40 ft

Prop Pack

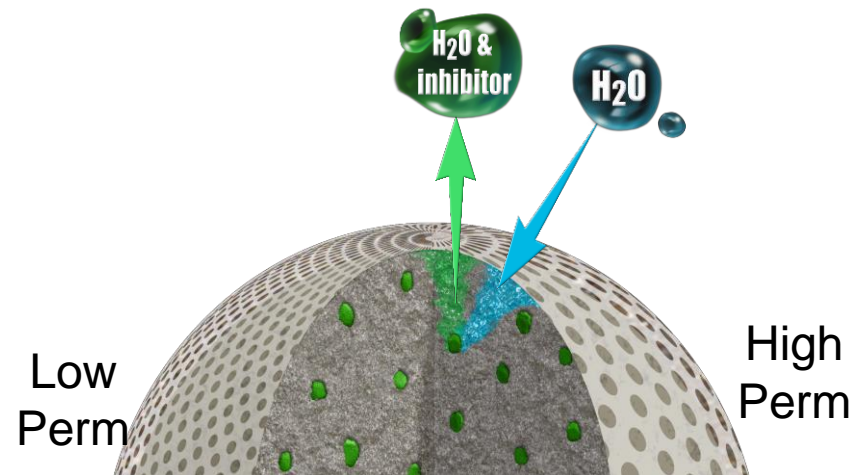
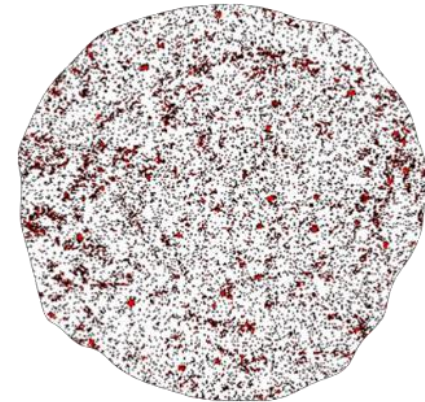
5 1/2"	Production Rate, bpd	50,000	30,000
	Delta P of Pack, psi	450	540
	Production Index, bbl/psi	111	56
7 5/8"	Production Rate, bpd	50,000	50,000
	Delta P of Pack, psi	260	560
	Production Index, bbl/psi	192	96



Infused Prop Platform Technology Enablers

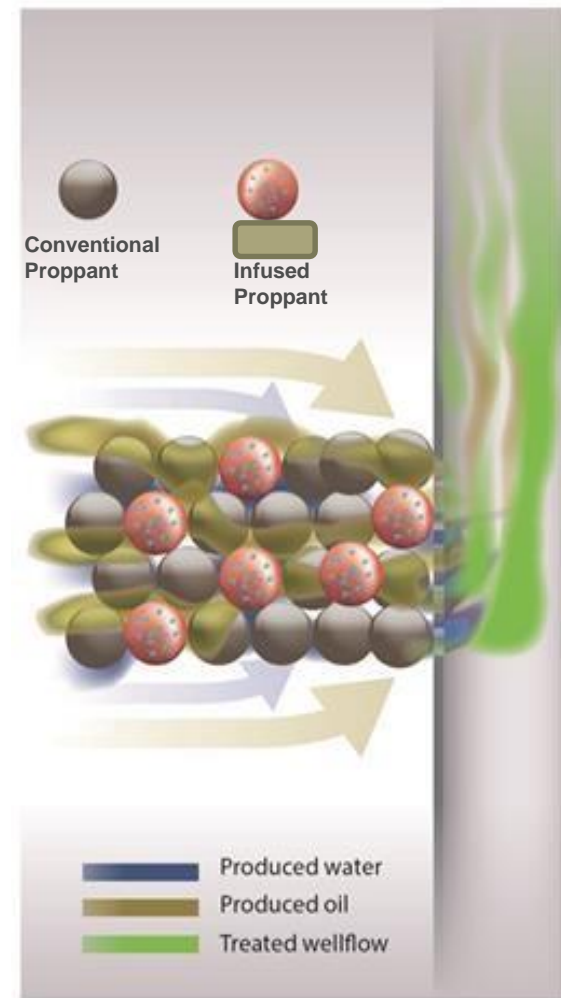
- Engineered Porous Ceramic Grains
 - Uniform and interconnected porosity
 - Maximizes strength
- Advanced Chemical Delivery
 - Chemical infusion throughout the pellet
 - Allows for larger volume of chemicals
- Controlled Release
 - Engineered permeable membranes (coatings)
 - Significant reduction in initial chemical loss
 - No UCS loss when used with resin coated proppant system
- Optimal Placement
 - In fracture at the point of production
 - Inhibits entire system: more efficient, longer lasting

Cross-section of infused proppant grain



Infused Proppant Technologies for Producers

- Typically replaces < 2% of proppant volume
 - Design based on pound of product required
 - No loss in fracture conductivity (it is a proppant)
- Controlled release technology – only releases when in contact with target production fluids
- Treats multiple years without additional cost to AFE (800 days since 1st jobs with no known workovers)



Summary

- Novel resin coated, ceramic proppant pack system is robust, cost effective & commercially viable for deepwater injectors and producers
- Non-Radioactive Tracer in proppant grains allows evaluation of the propped frac height & qualitative analysis of the annular pack
 - Memory Neutron logging solution a must to reduce costs in deepwater
- New porous ceramic proppant infused with production chemicals adds another dimension to enhance and maintain production
- Developing very low cost sand control options for land based injectors and producers
- Applications are only limited by our imagination!



Acknowledgements, References & Questions

- Co-authors: Todd Roper, CARBO Resin R&D Mgr
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- Scott Woolfolk, CARBO New Iberia Manufacturing & Applications Lab

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- Shell Technology & Gulf Of Mexico
- Hilcorp USA

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*Thanks for your time and interest,
Questions?*

