

VISCOELASTIC SURFACTANTS FOR OIL RECOVERY

OIL PRODUCTION

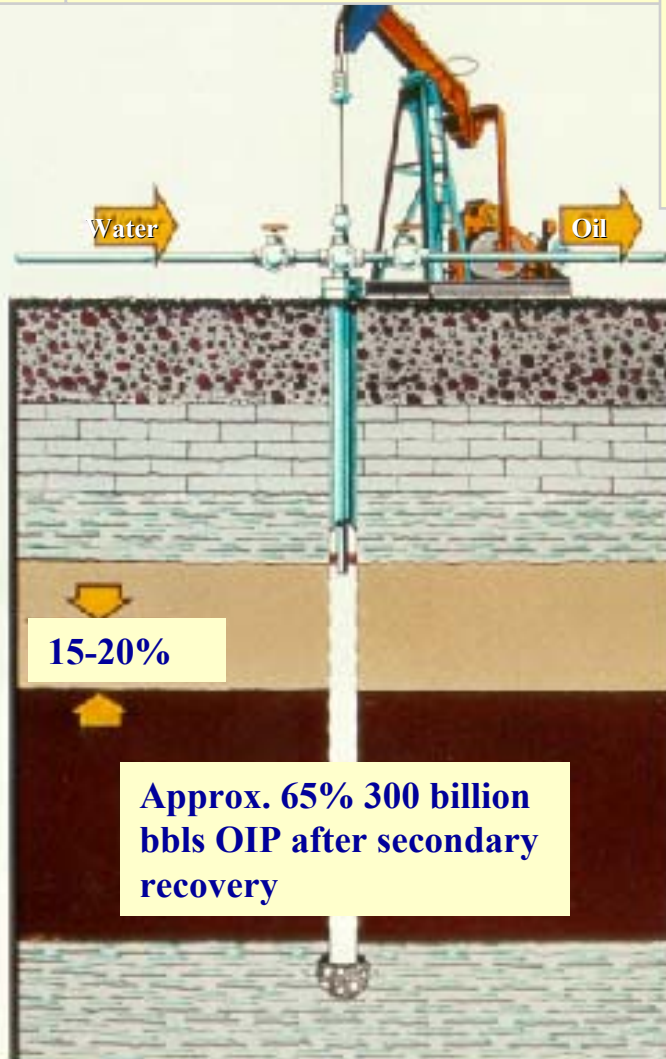
PRIMARY RECOVERY

Produces 2-15% Original Oil in Place



SECONDARY RECOVERY

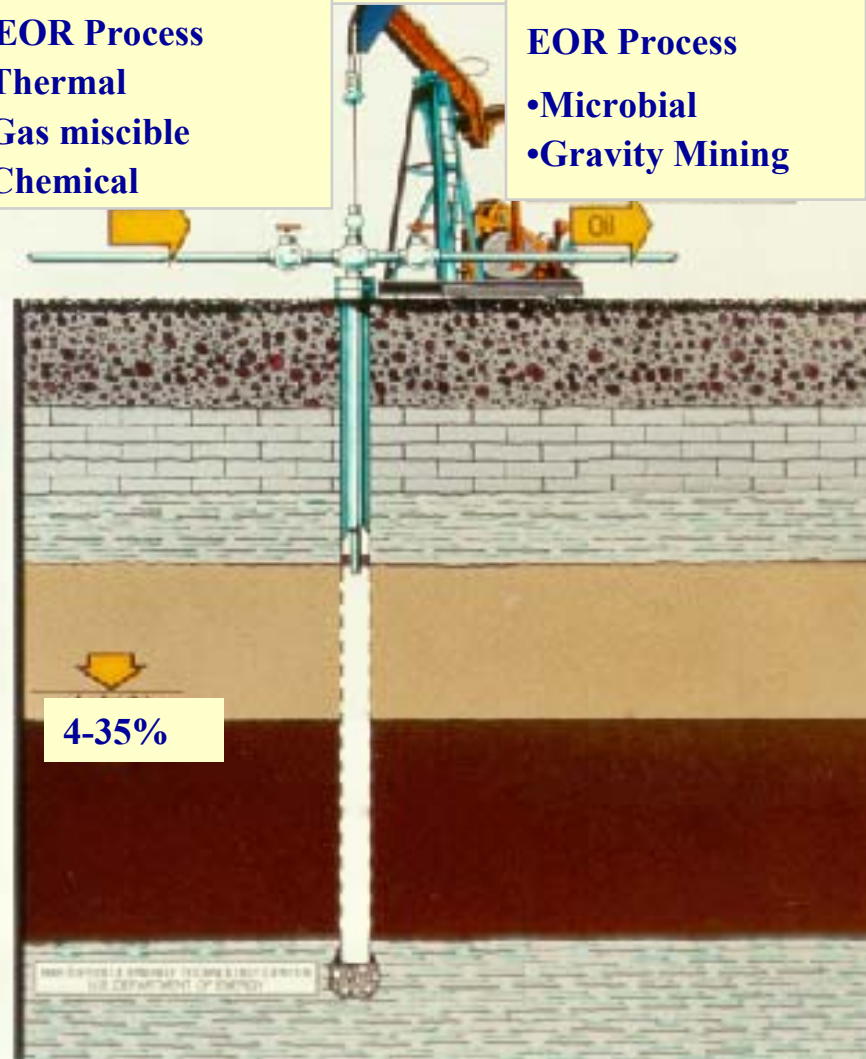
Another 15-20% OOIP may be produced by water flooding



ENHANCED OIL RECOVERY

Another 4-35% OOIP may be produced by EOR

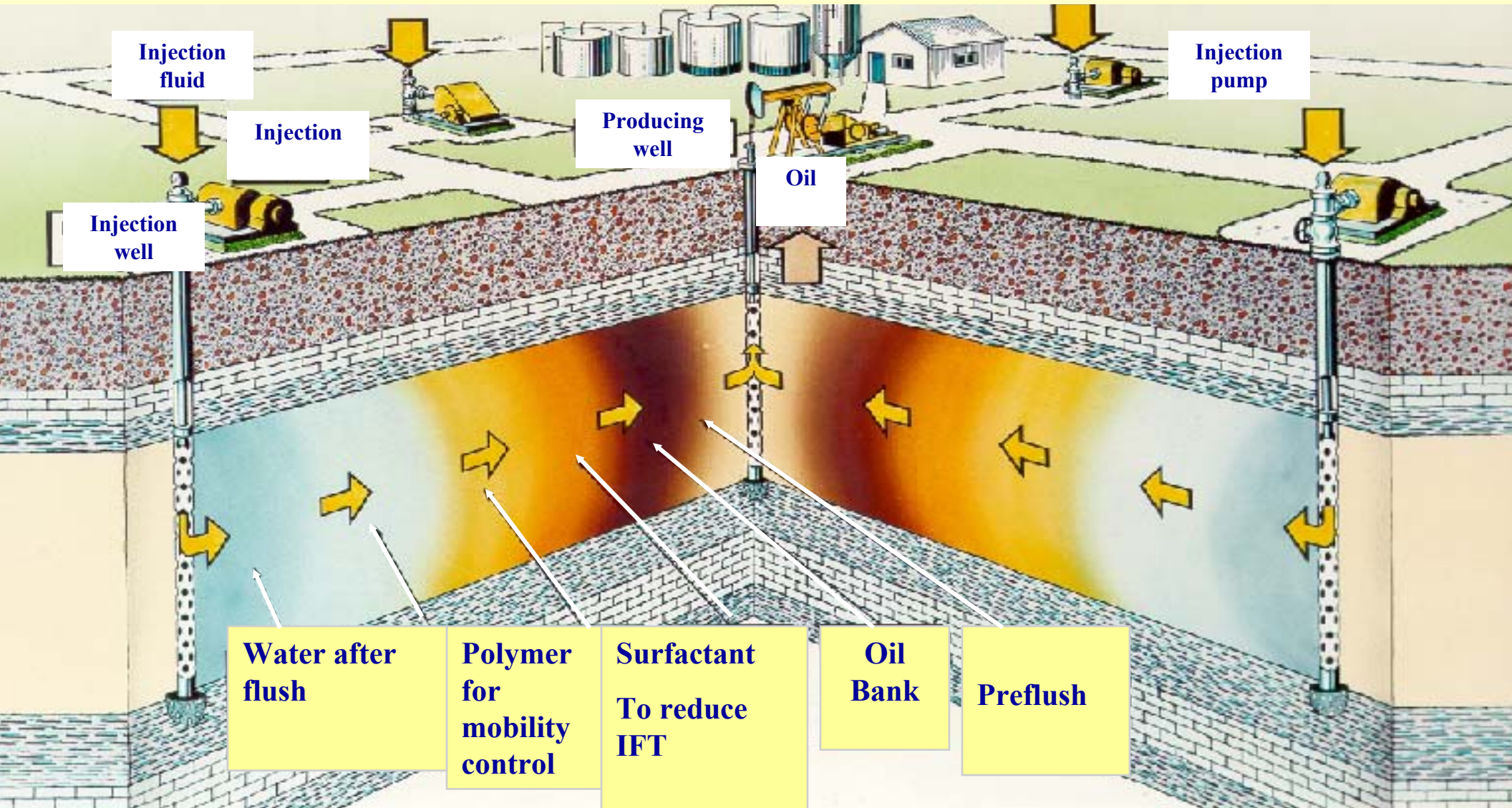
- EOR Process
- Thermal
 - Gas miscible
 - Chemical



- EOR Process
- Microbial
 - Gravity Mining

CHEMICAL EOR

EOR may include surfactant, polymer and alkaline flooding. After a reservoir is conditioned by a water preflush, specific chemicals are injected to reduce the IFT (help to release oil) and improve mobility control (reduce channeling)



TWO PRIMARY MECHANISMS IN CHEMICAL EOR

- Reduce interfacial forces
- Improve sweep efficiency & mobility ratio

TWO PRIMARY MECHANISMS IN CHEMICAL EOR

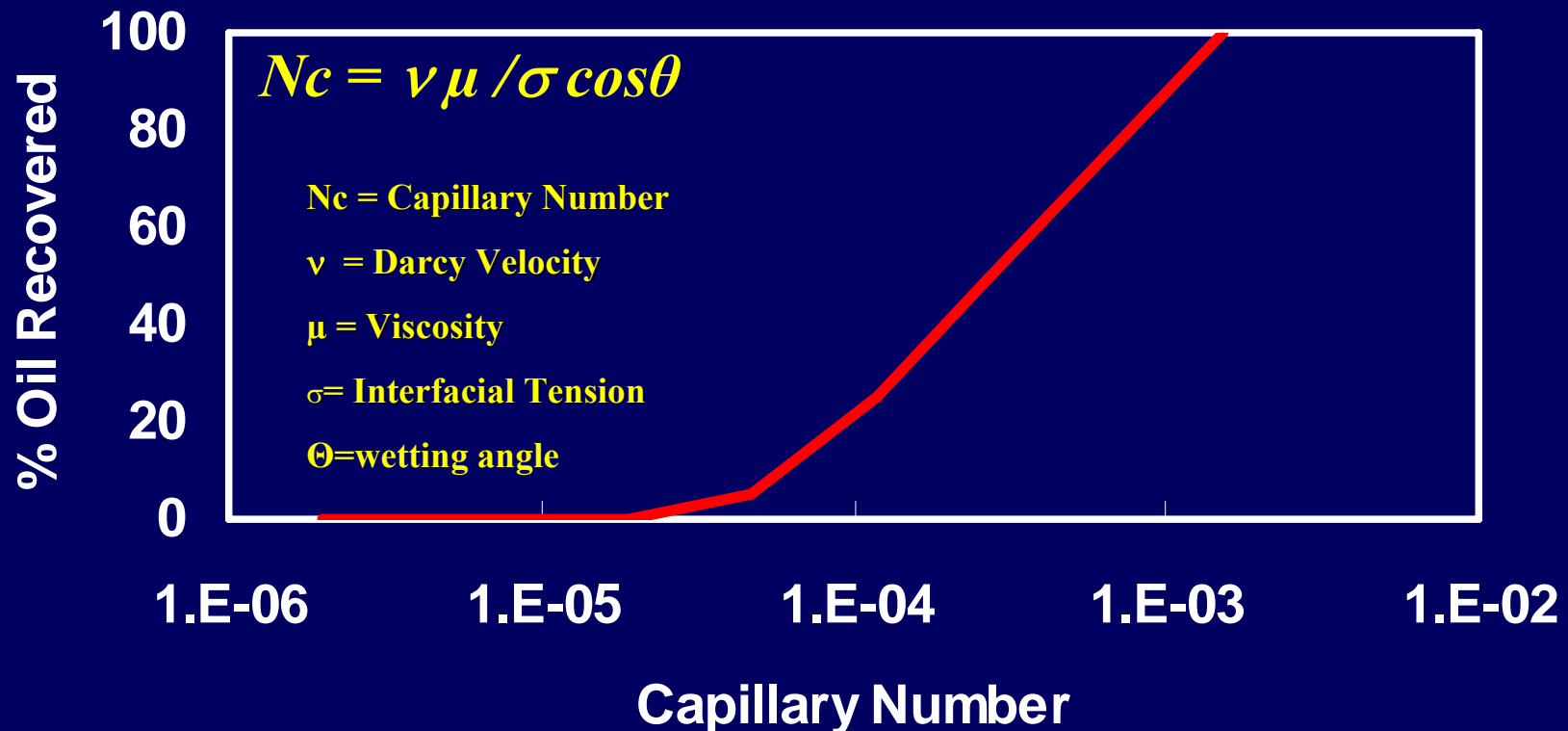
- **Reduce interfacial forces**
 - **surfactants**
- **Improve sweep efficiency & mobility ratio**

ROLE OF IFT

SURFACE TENSION & INTERFACIAL TENSION

Description	ST or IFT, mN/m
Water	72
Oil	6-40
Oil/Water	3-30
O/W with 0.05-0.2% EOR surfactant	<0.01

RELATIONSHIP BETWEEN CAPILLARY NUMBER AND OIL RECOVERY



TWO PRIMARY MECHANISMS IN CHEMICAL EOR

- Reduce interfacial forces
 - Surfactants
- Improve sweep efficiency & mobility ratio

TWO PRIMARY MECHANISMS IN CHEMICAL EOR

- Reduce interfacial forces
 - Surfactants
- Improve sweep efficiency & mobility ratio
 - Polymers

OIL CONTAINING CORE

INJECTION FLUID CAN CHANNEL THROUGH LARGE FRACTURES AND BY-PASS OIL

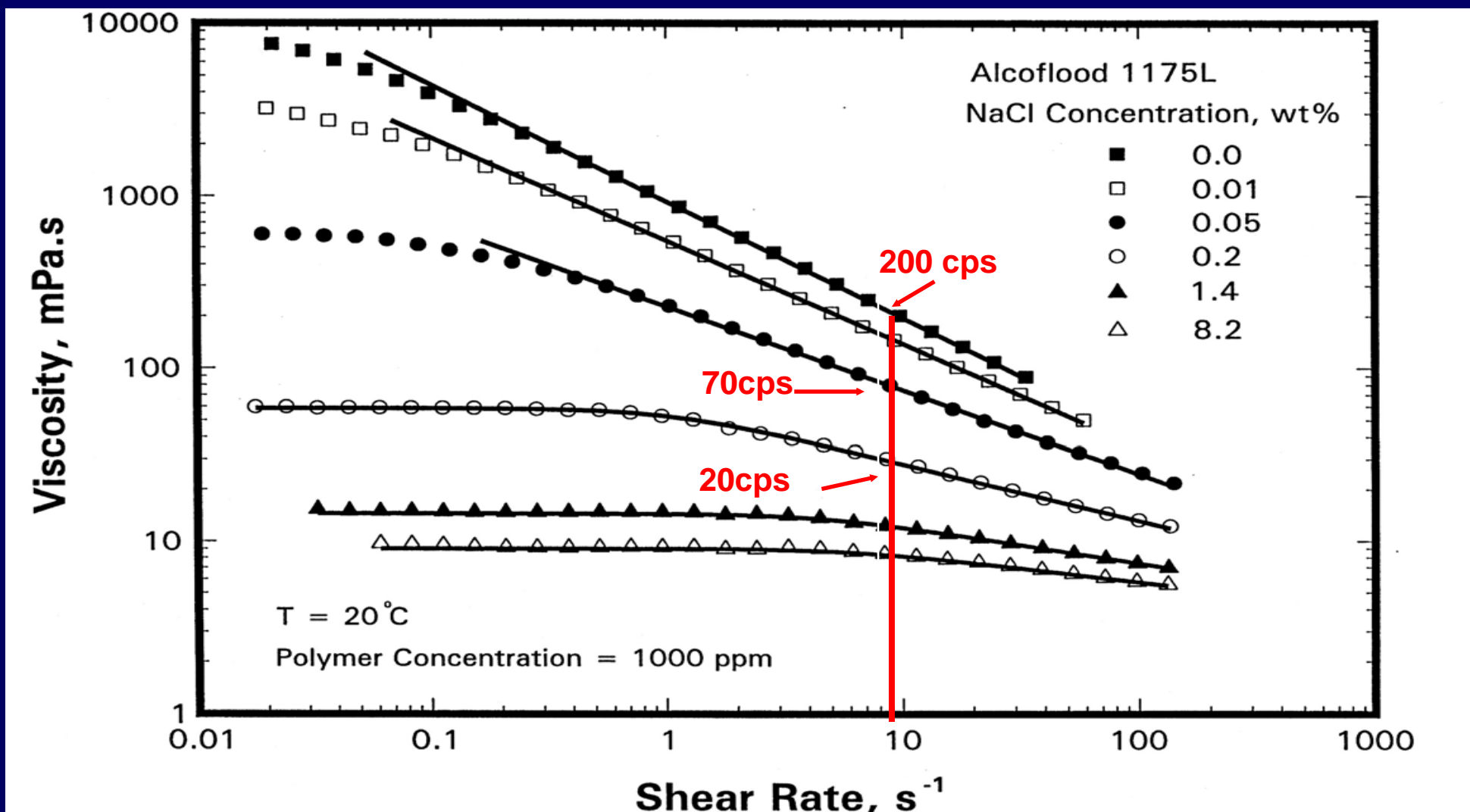
FRACTURES



POLYMERS USED IN EOR

POLYMER	HIGH TEMP	HIGH TDS	HIGH SHEAR	COST
Polyacrylamide	75°C	poor	poor	low
AMPS copolymer	90°C	fair	poor	medium
Xanthan gum	50°C	fair	fair	high
Scleroglucan	100°C	fair	fair	high

EFFECT OF SALT ON VISCOSITY



TWO PRIMARY MECHANISMS IN CHEMICAL EOR

- Reduce interfacial forces
 - surfactants
- Improve sweep efficiency & mobility ratio
 - Polymers
 - Viscoelastic surfactants

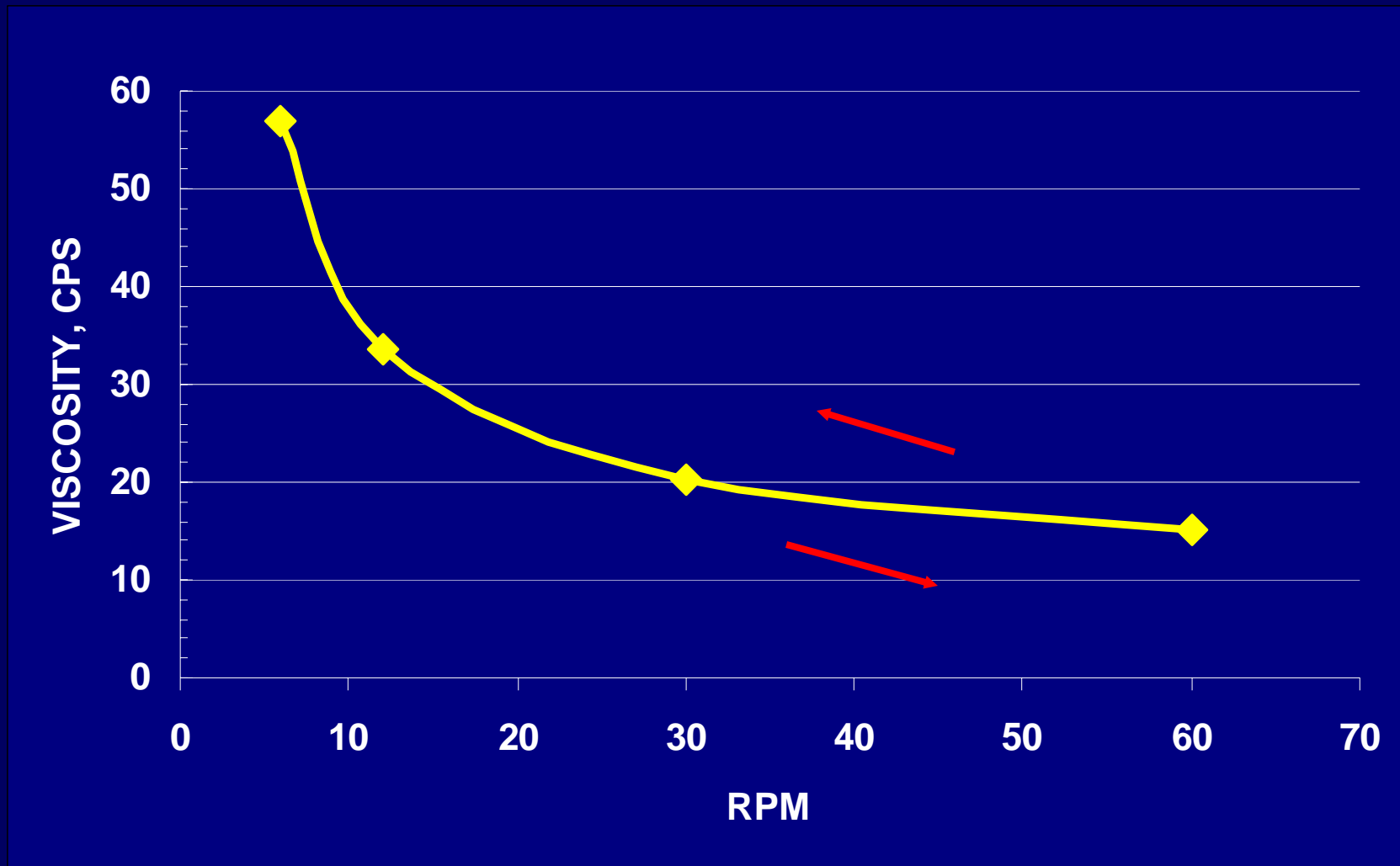
VISCOELASTIC SURFACTANT

- Forms viscoelastic solution at 0.1-1.0 wt%
- Reduces IFT to below 0.01 mN/m
- Tolerant to high TDS and hardness
- Shear thinning and reversible
- Viscosity is reduced when contacted with oil
- Diverts injection fluid to oil bearing sites
- Thermal stability above 150C

POLYMERS USED IN EOR

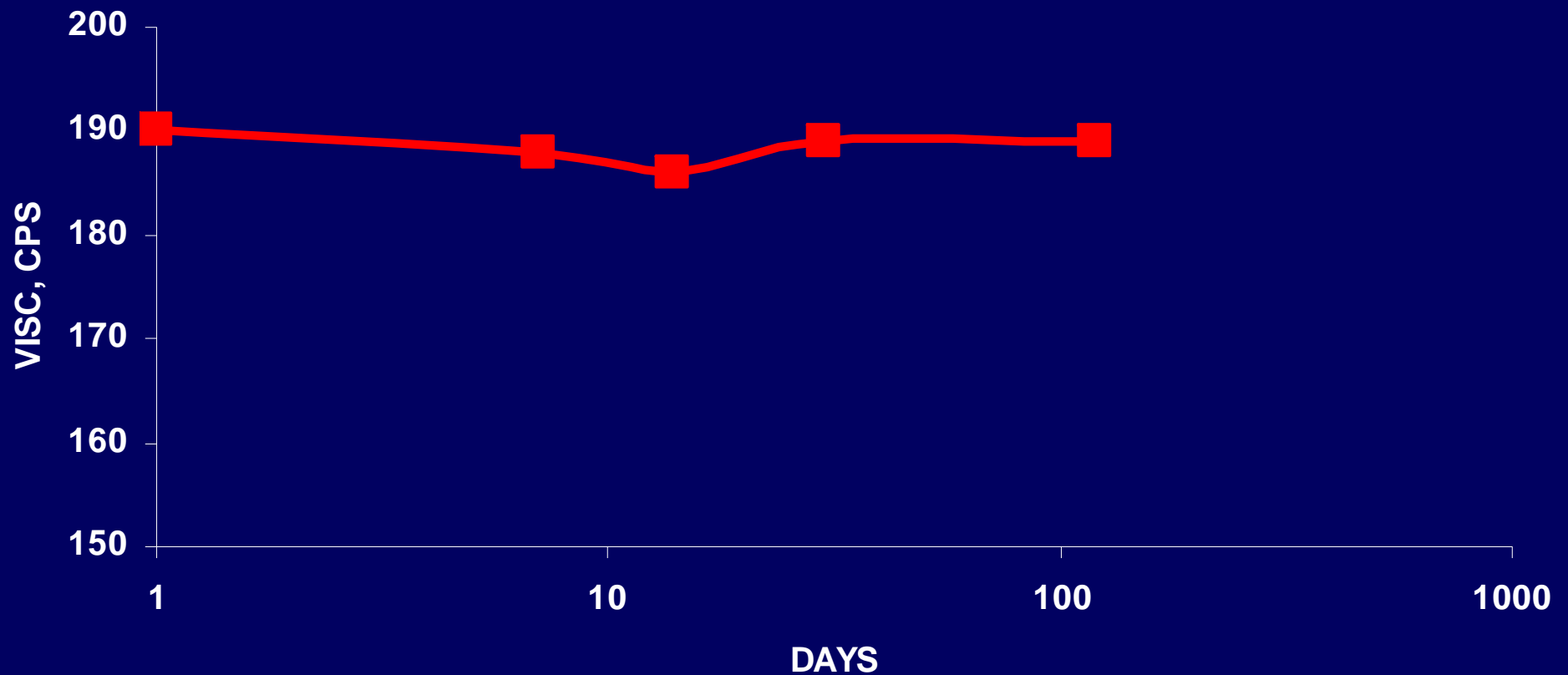
POLYMER	HIGH TEMP	HIGH TDS	HIGH SHEAR	COST
Polyacrylamide	75°C	poor	poor	low
AMPS copolymer	90°C	fair	poor	medium
Xanthan gum	50°C	fair	fair	high
Scleroglucan	100°C	fair	fair	high
Viscoelastic surf.	150°C	excellent	excellent	low

EFFECT OF SHEAR ON VISCOELASTIC SURFACTANT



EFFECT OF TEMPERATURE

0.5% @150C



MECHANISM OF VISCOELASTIC SURFACTANT FLOODS

WATER FLOOD

**Water channels through
the formation**

WATER FLOOD



Injector



Producer



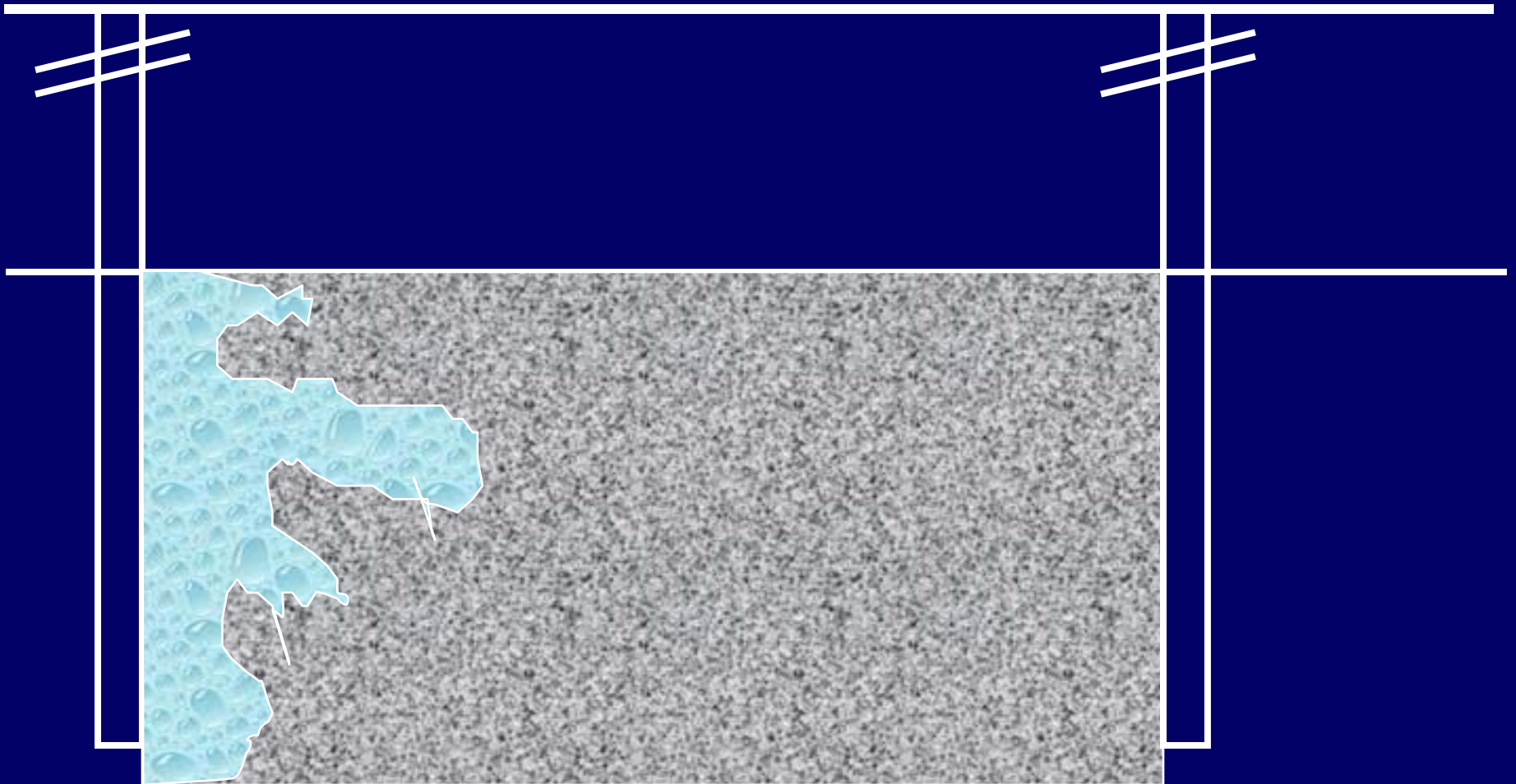
WATER FLOOD



Injector



Producer



WATER FLOOD



Injector



Producer



WATER FLOOD



Injector



Producer



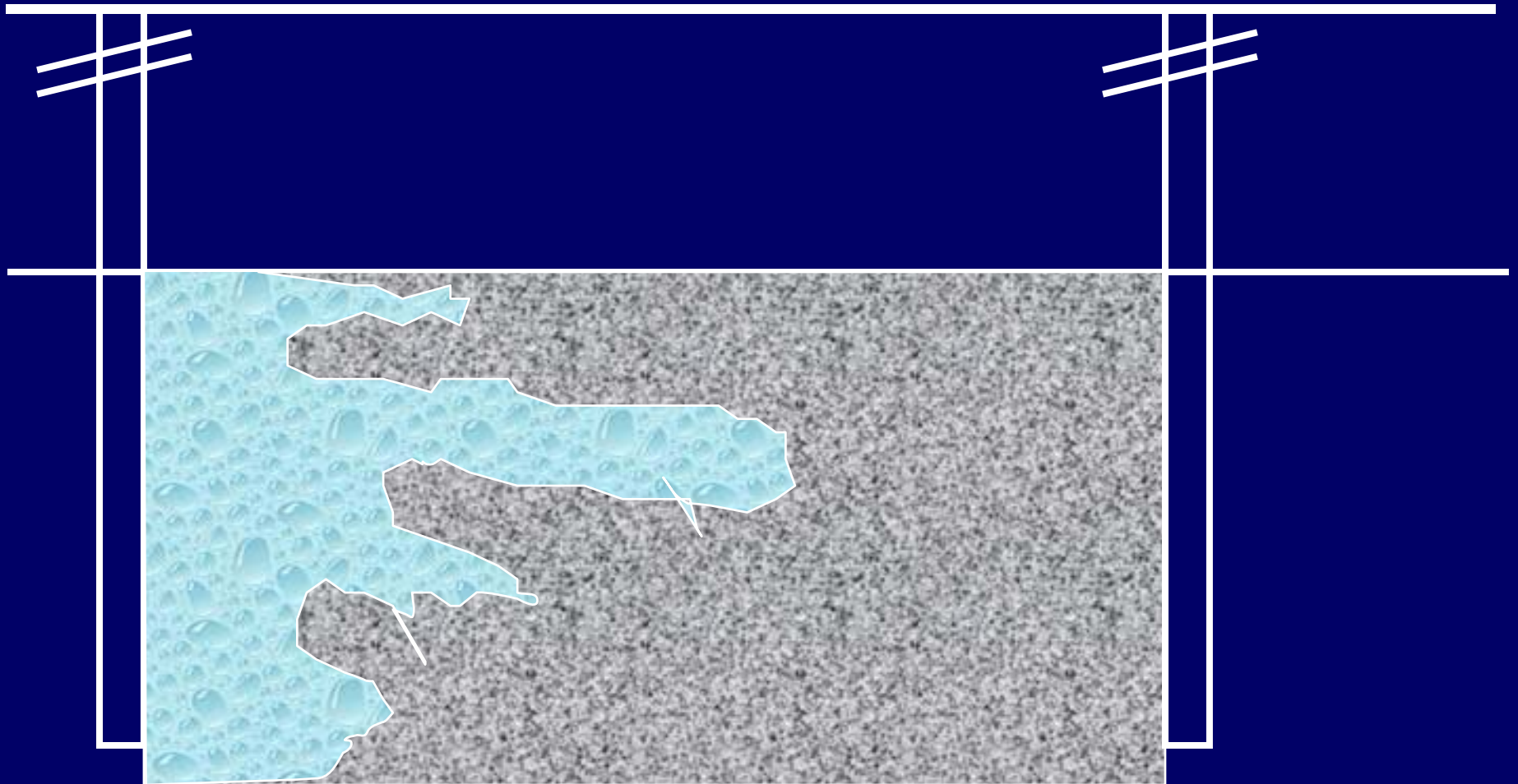
WATER FLOOD



Injector



Producer



WATER FLOOD



Injector



Producer



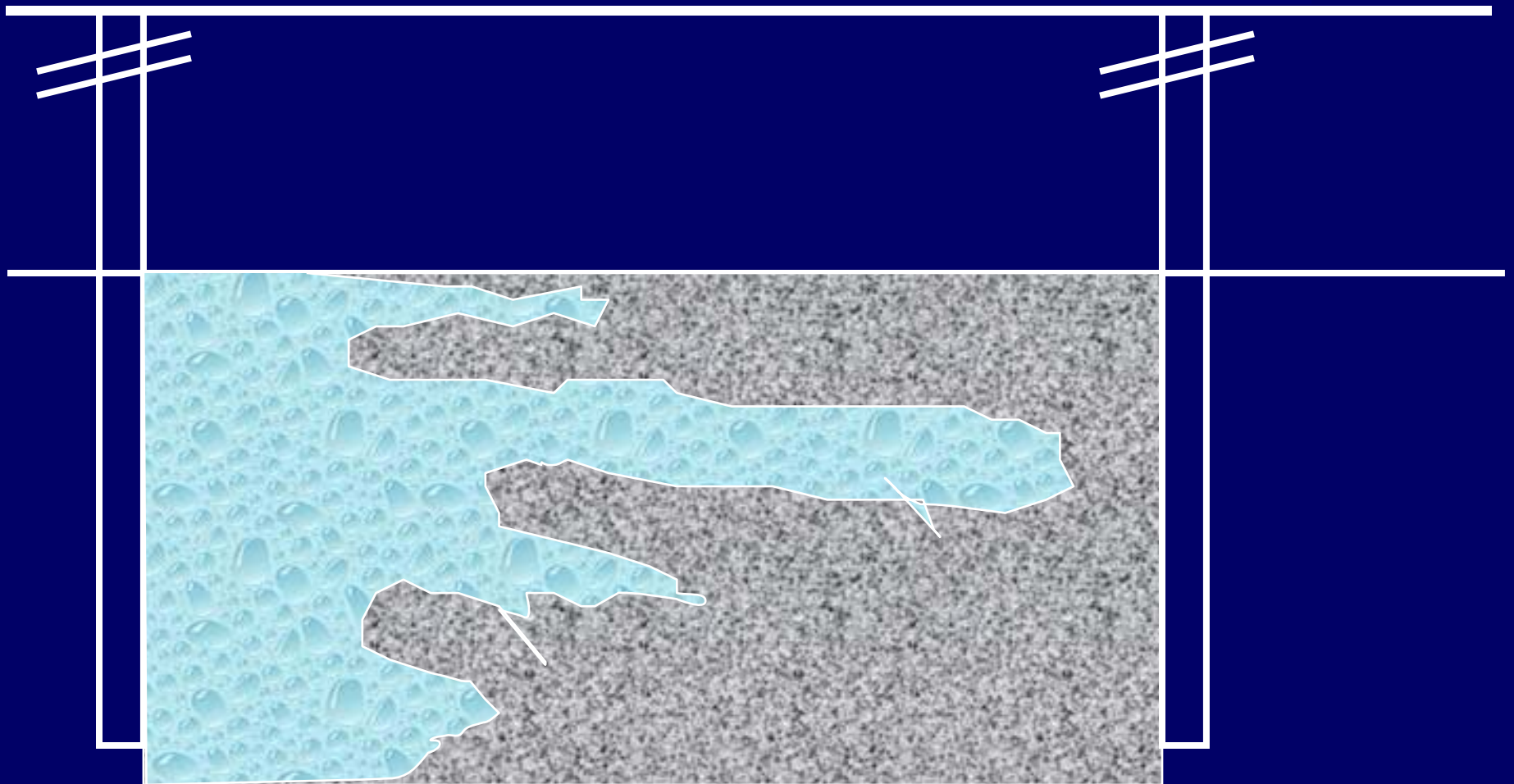
WATER FLOOD



Injector



Producer



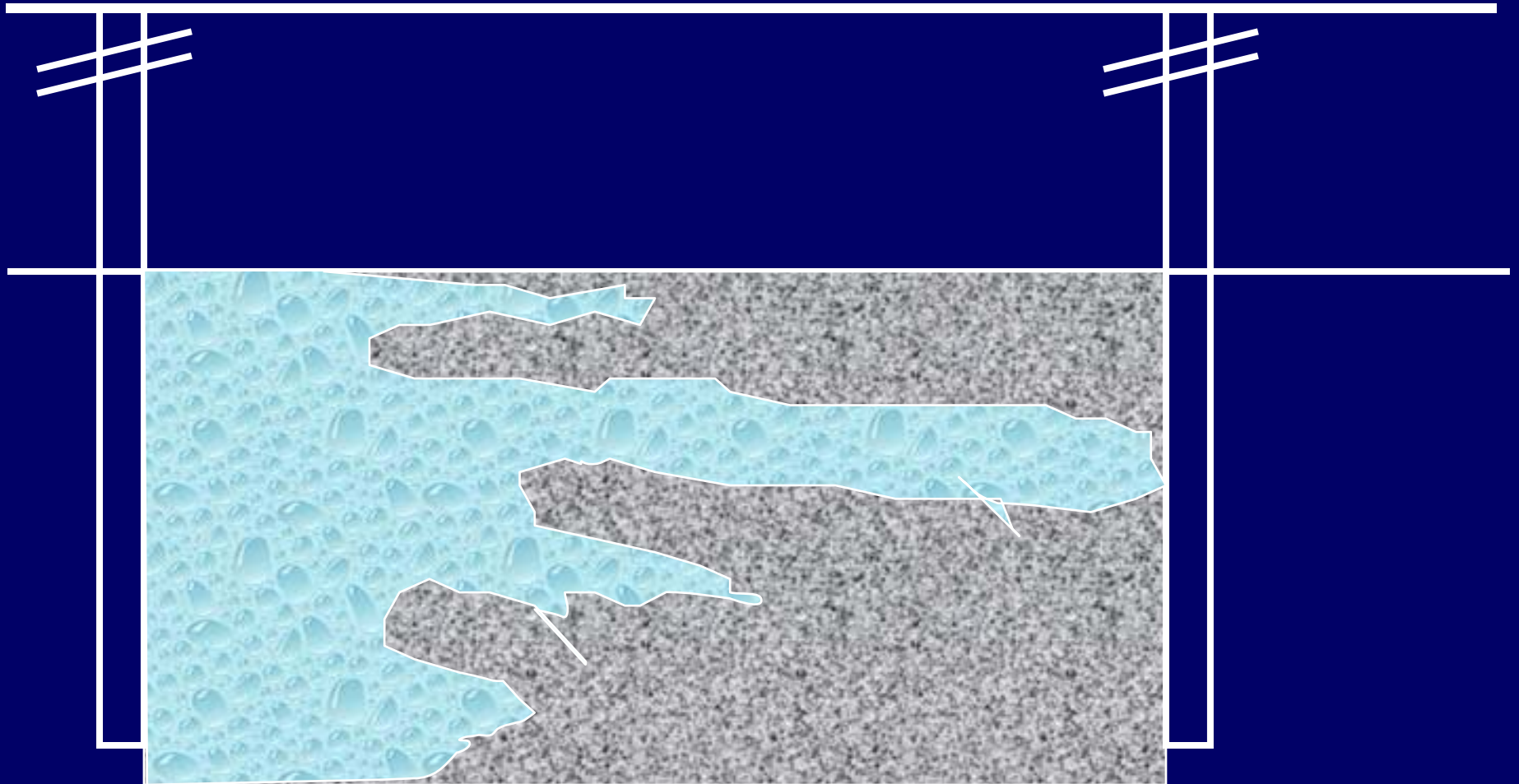
WATER FLOOD



Injector



Producer



SURFACTANT FLOOD

**Surfactant follows the
water channels through
the formation**

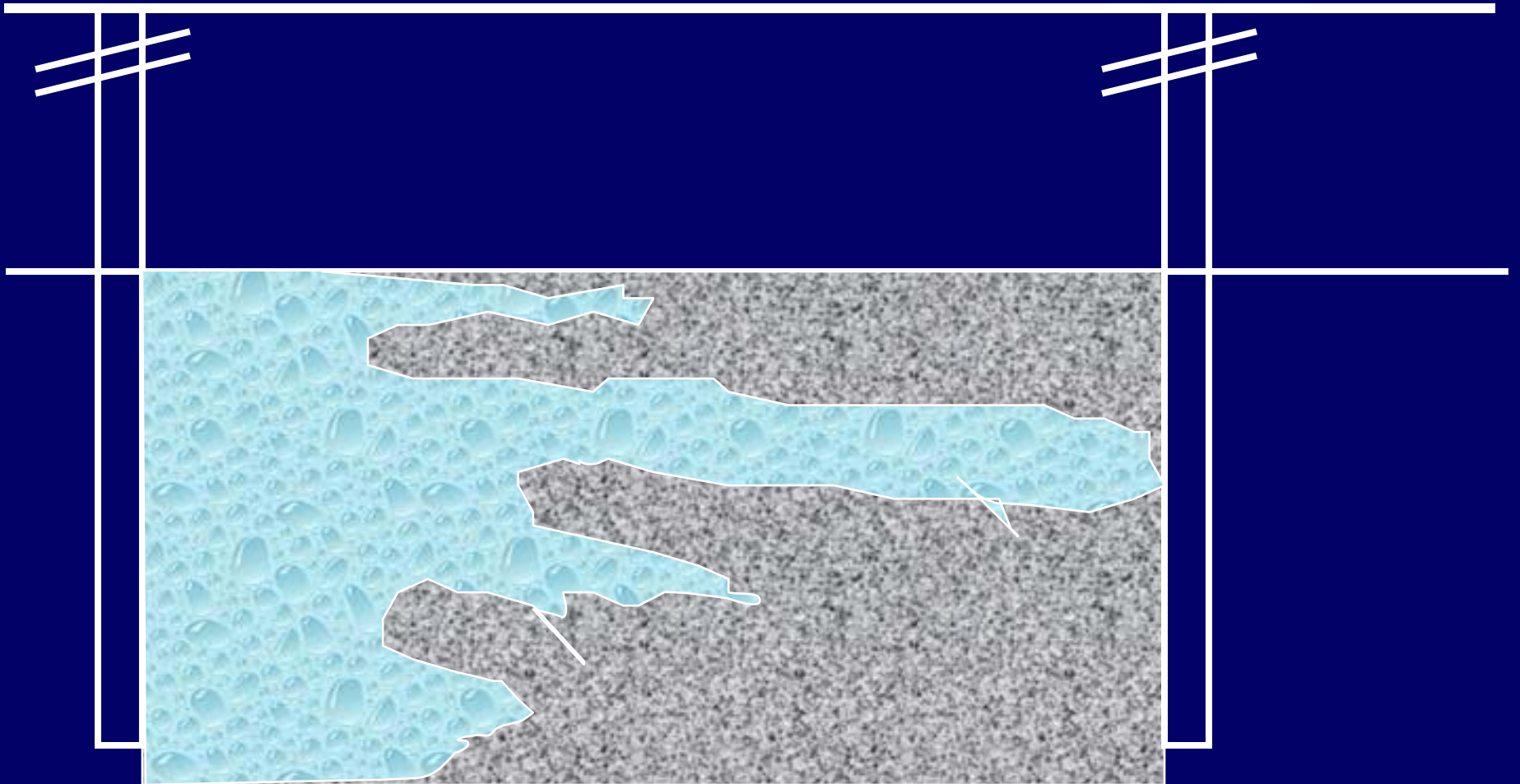
SURFACTANT FLOOD



Injector



Producer



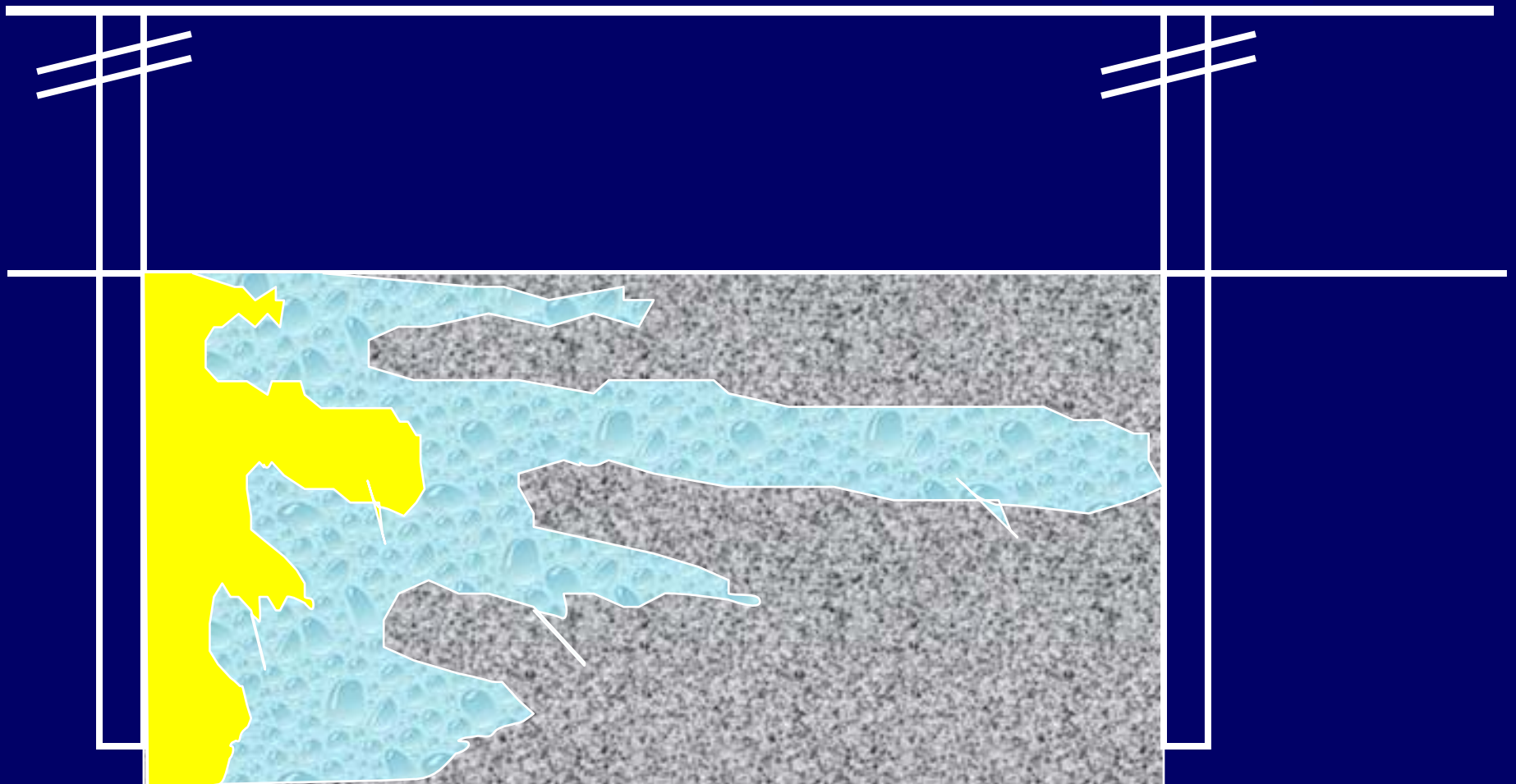
SURFACTANT FLOOD



Injector



Producer



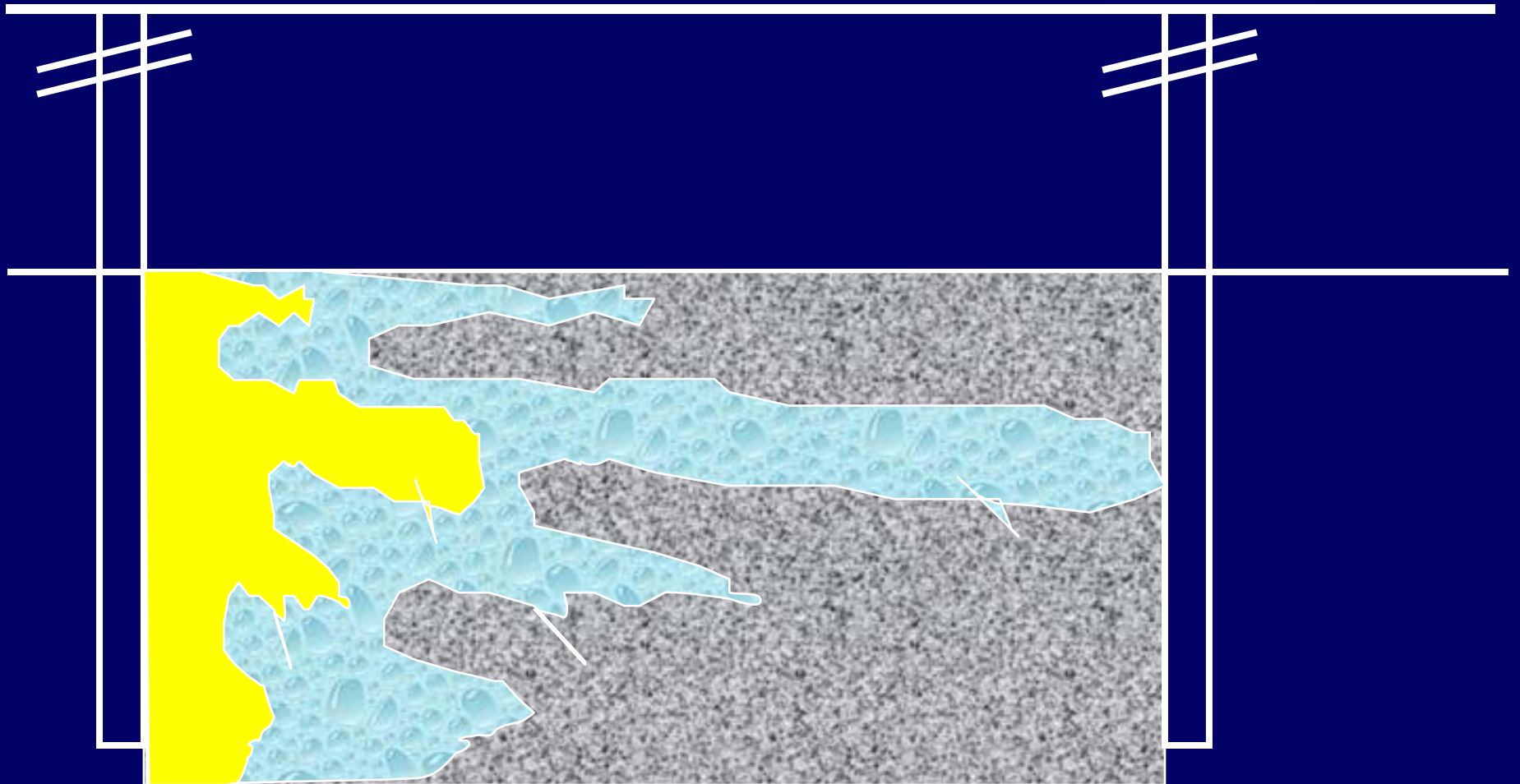
SURFACTANT FLOOD



Injector



Producer



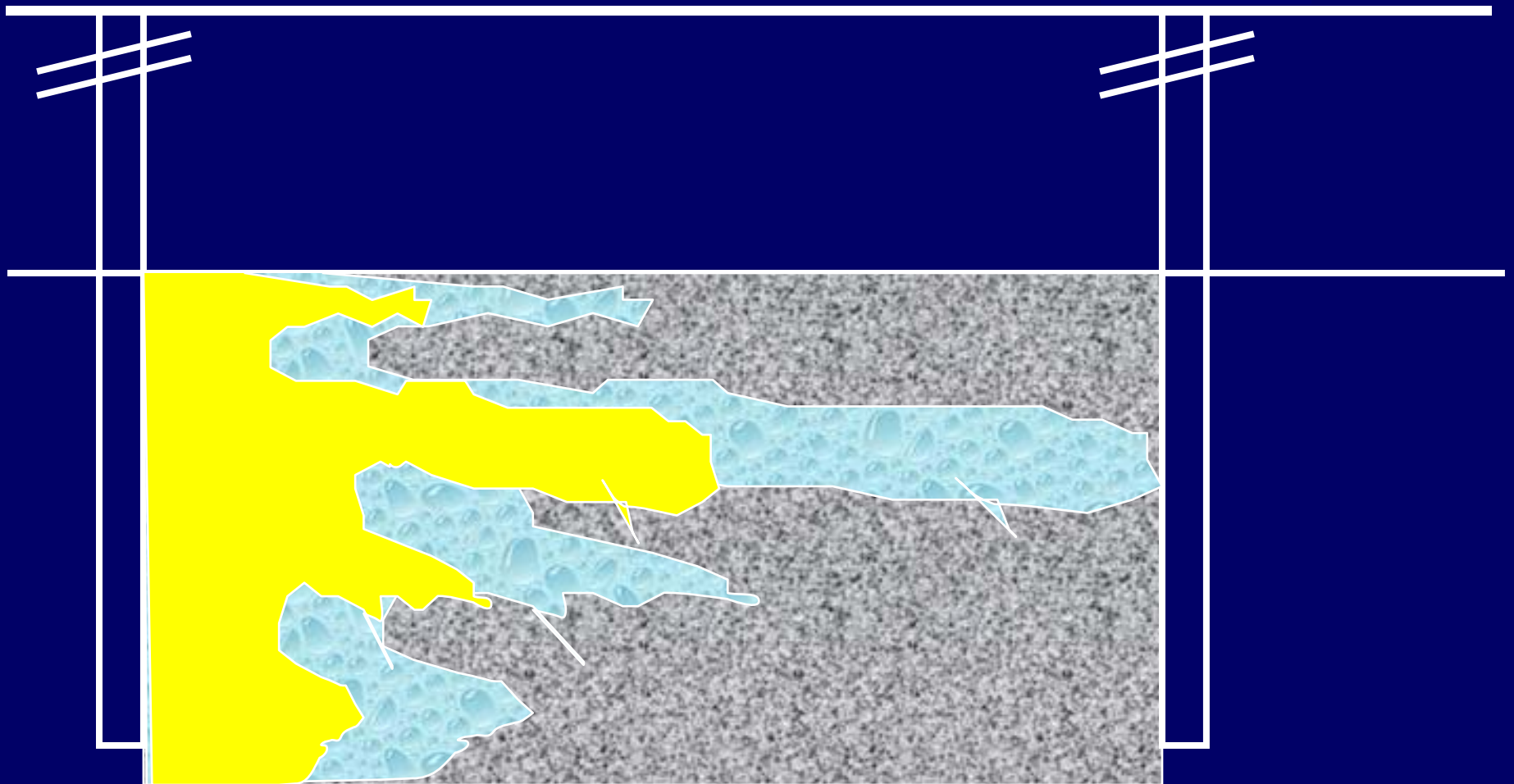
SURFACTANT FLOOD



Injector



Producer



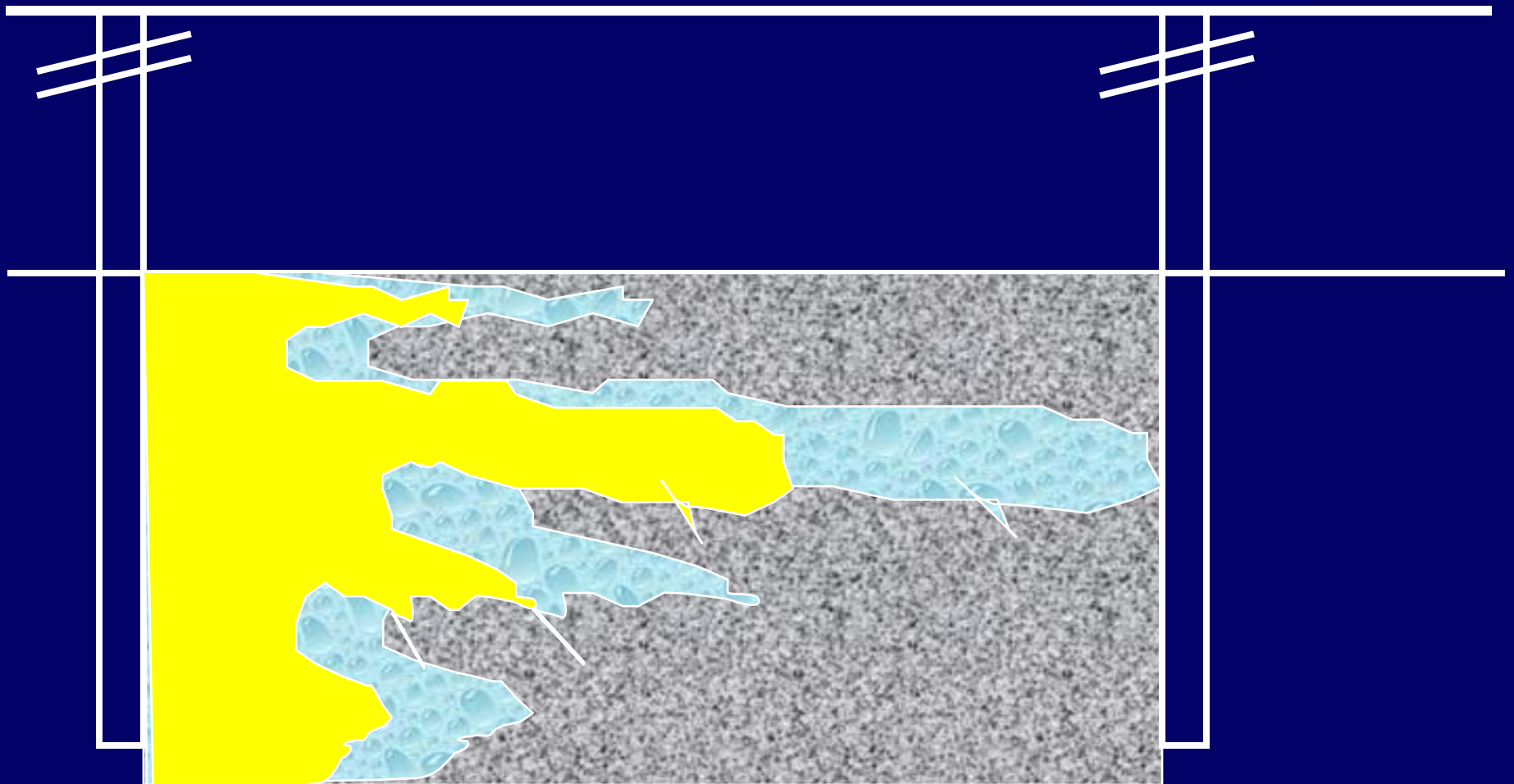
SURFACTANT FLOOD



Injector



Producer



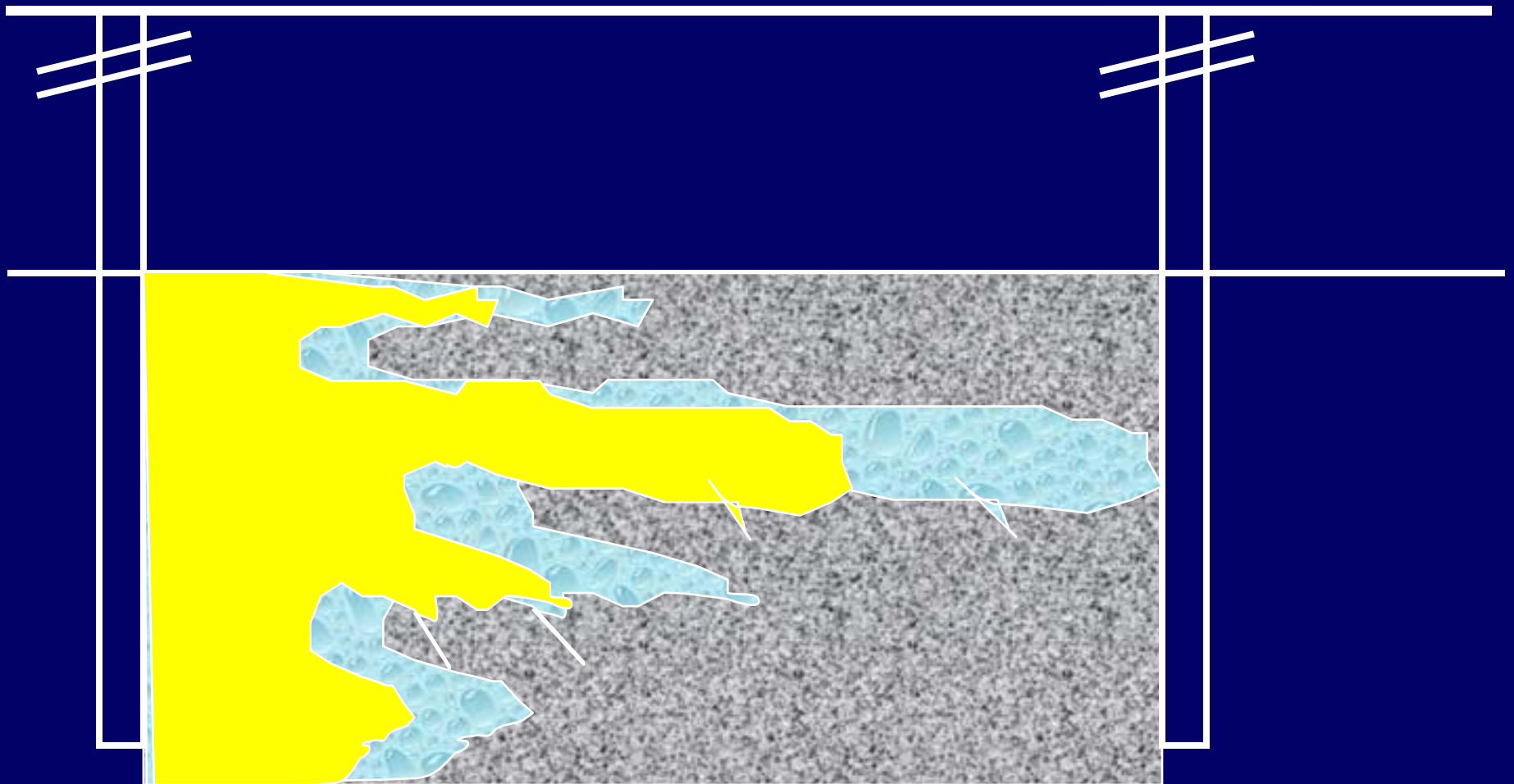
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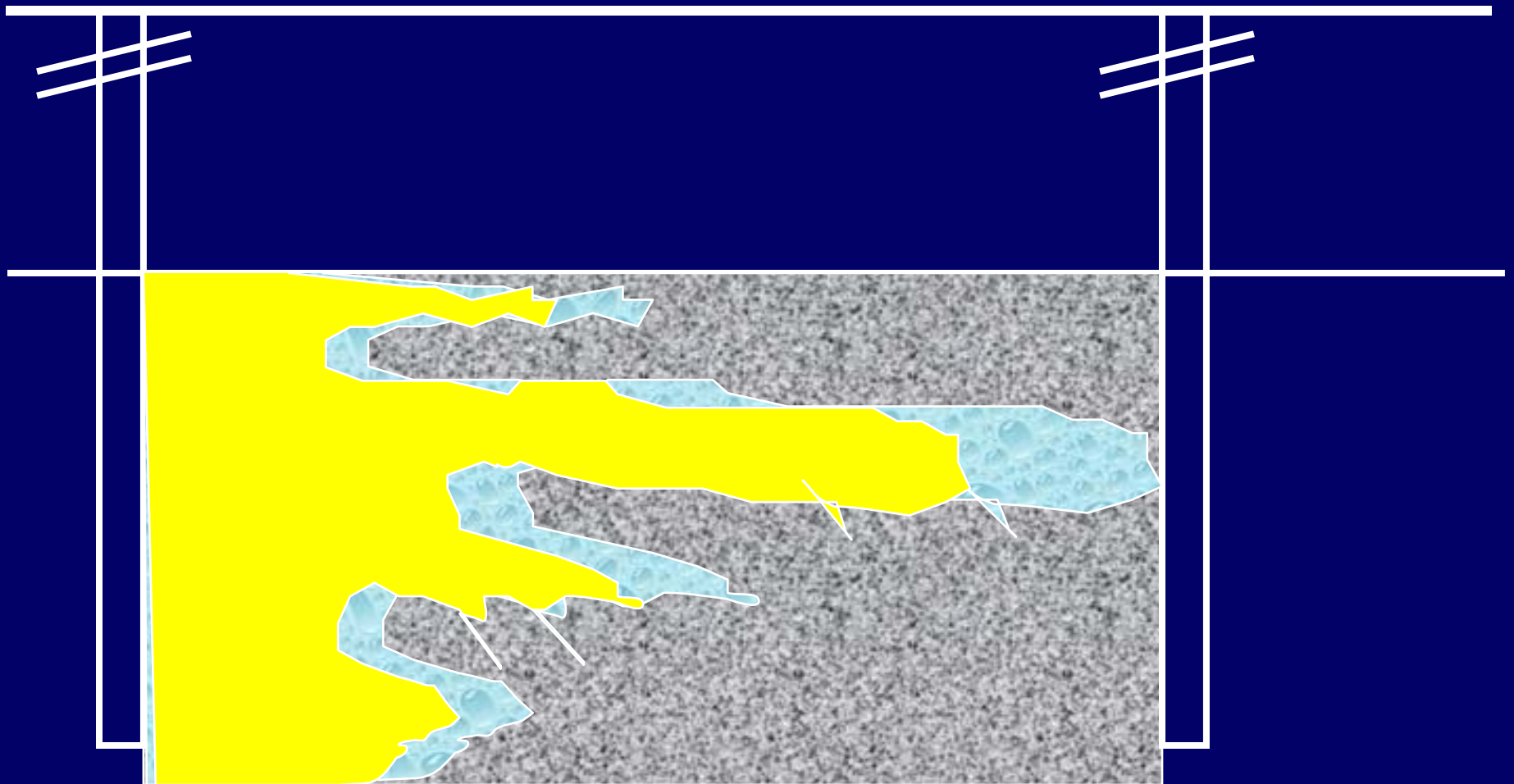
SURFACTANT FLOOD



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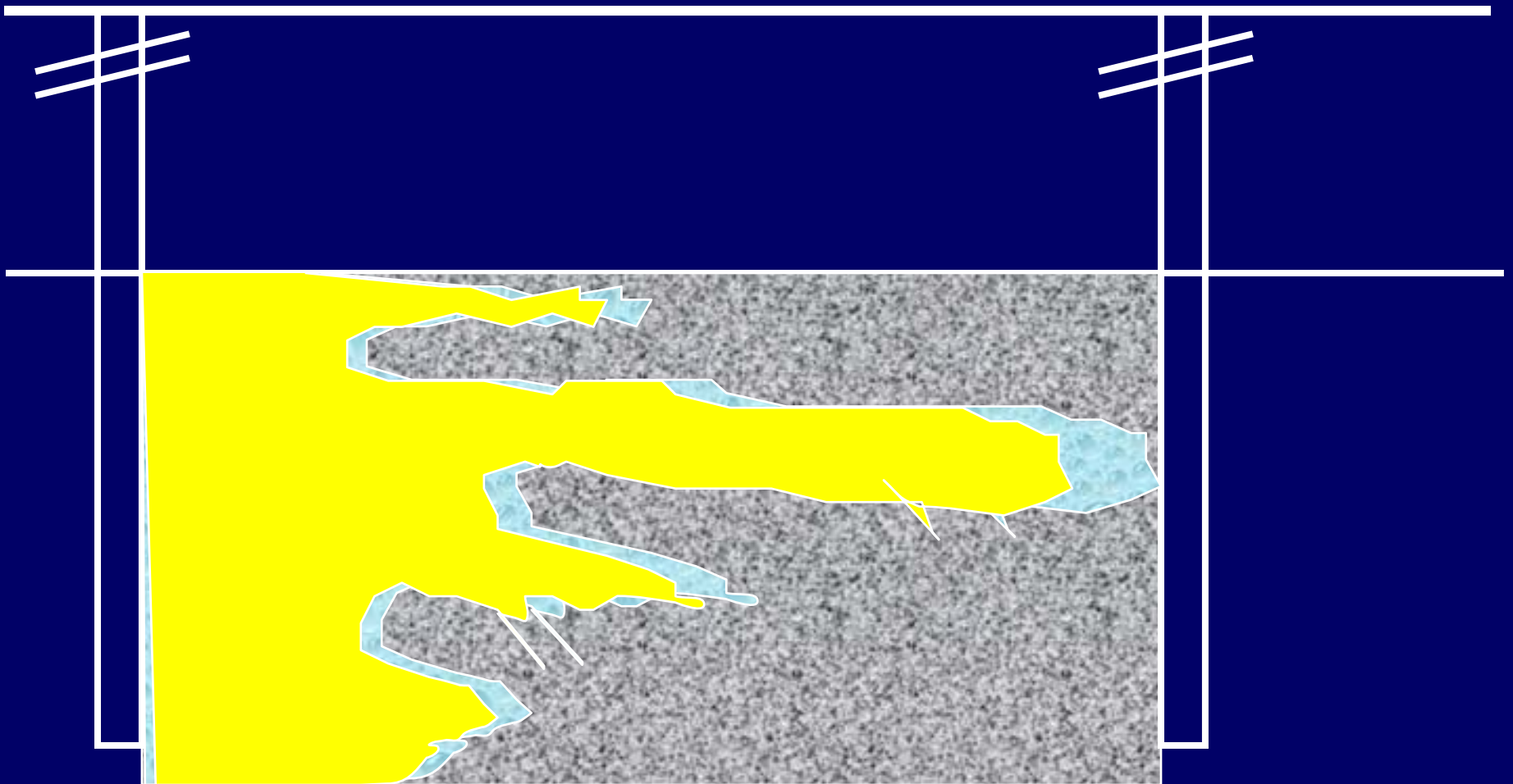
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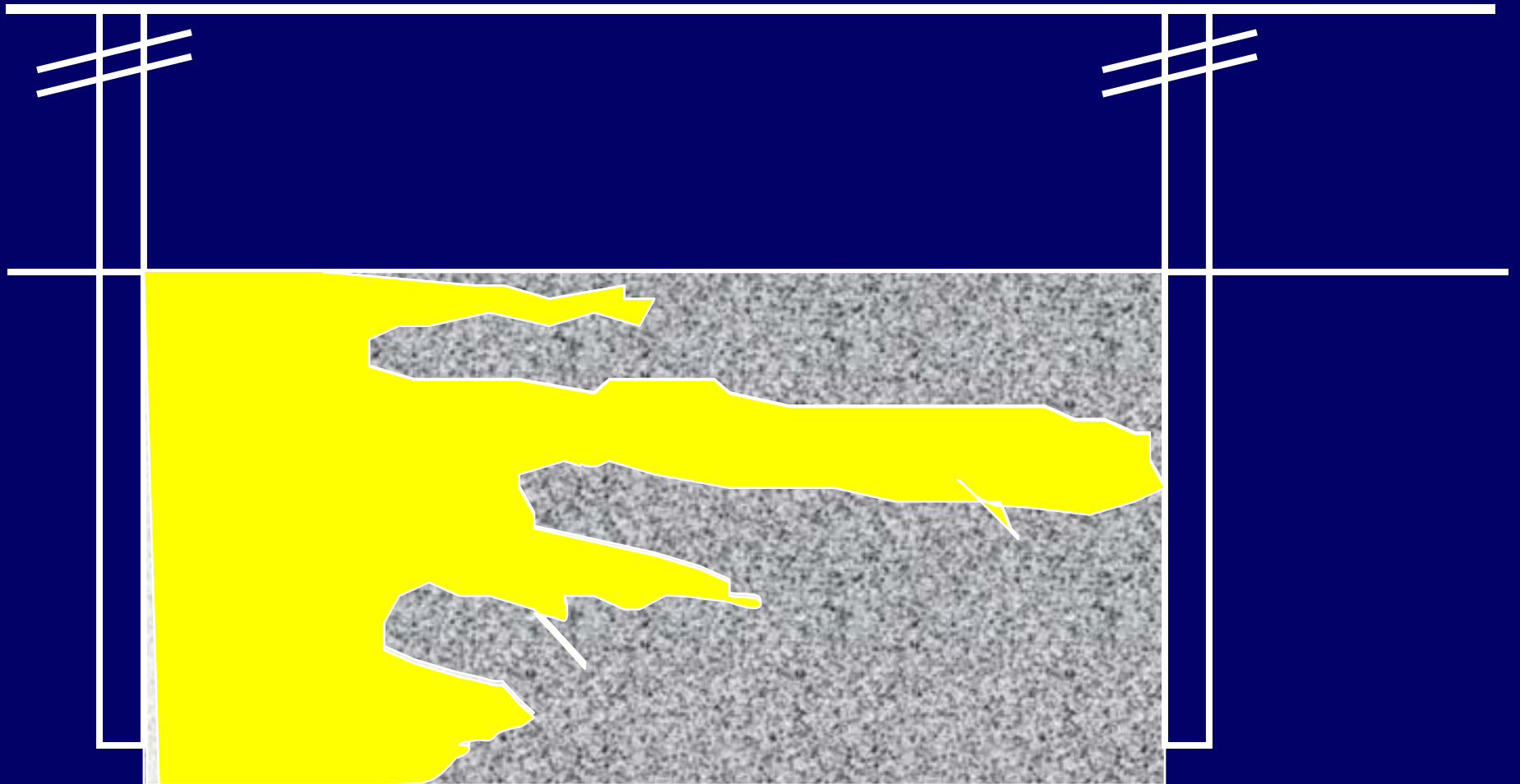
SURFACTANT FLOOD



Injector



Producer



VISCOELASTIC SURFACTANT FLOOD

**Injection fluid containing
viscoelastic surfactant seeks
out oil-bearing channels,
blocks water channels**

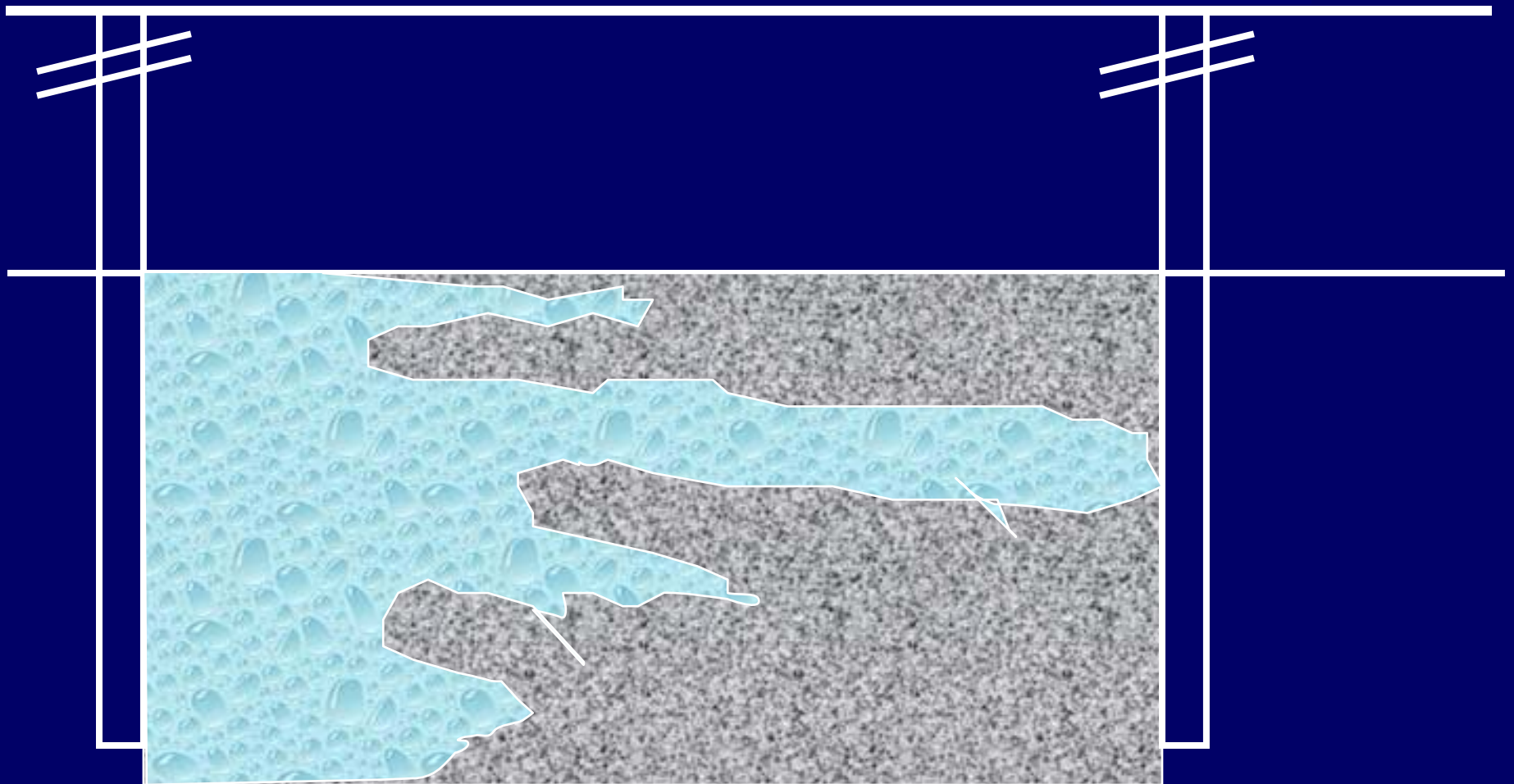
VISCOELASTIC SURFACTANT



Injector



Producer



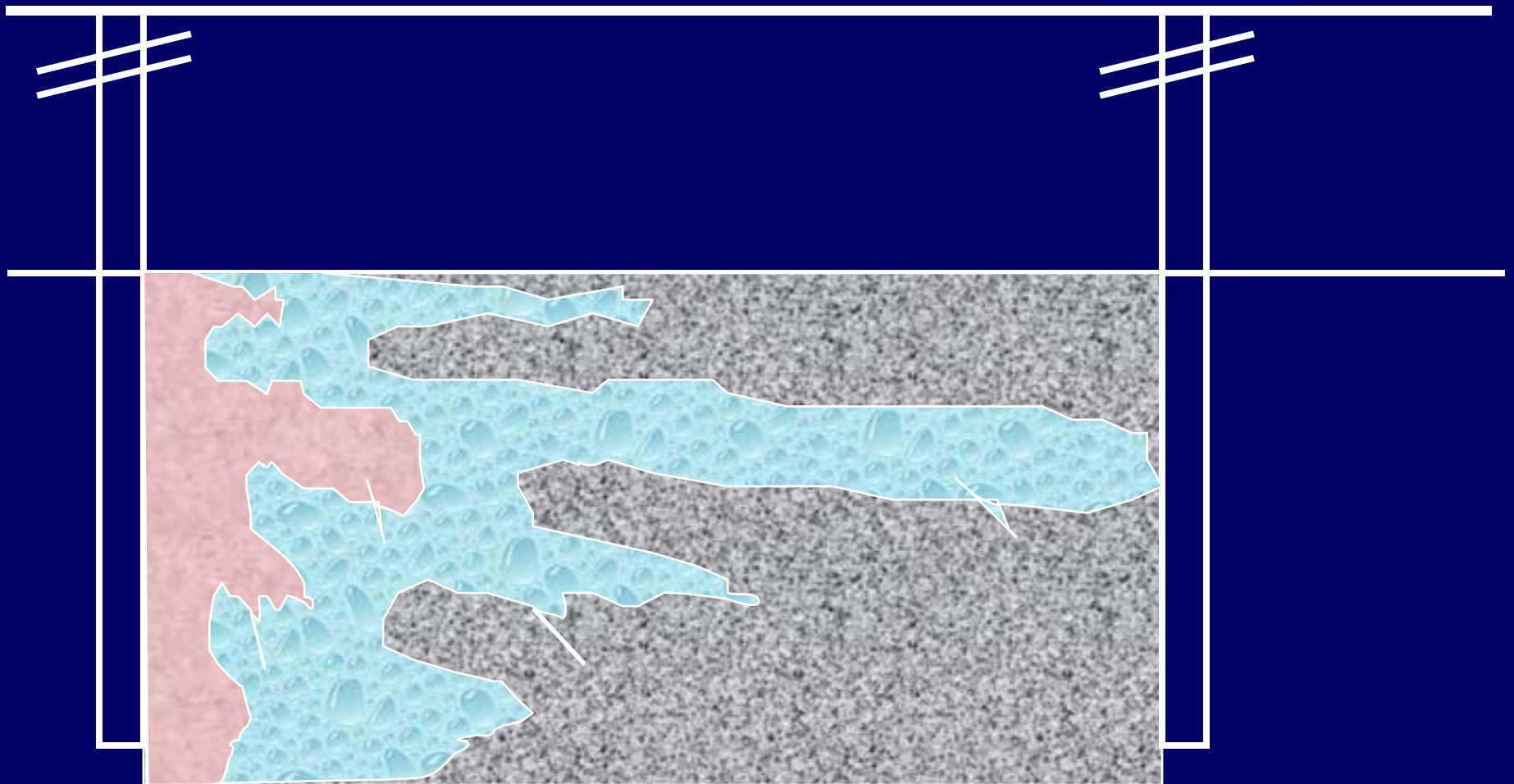
VISCOELASTIC SURFACTANT



Injector



Producer



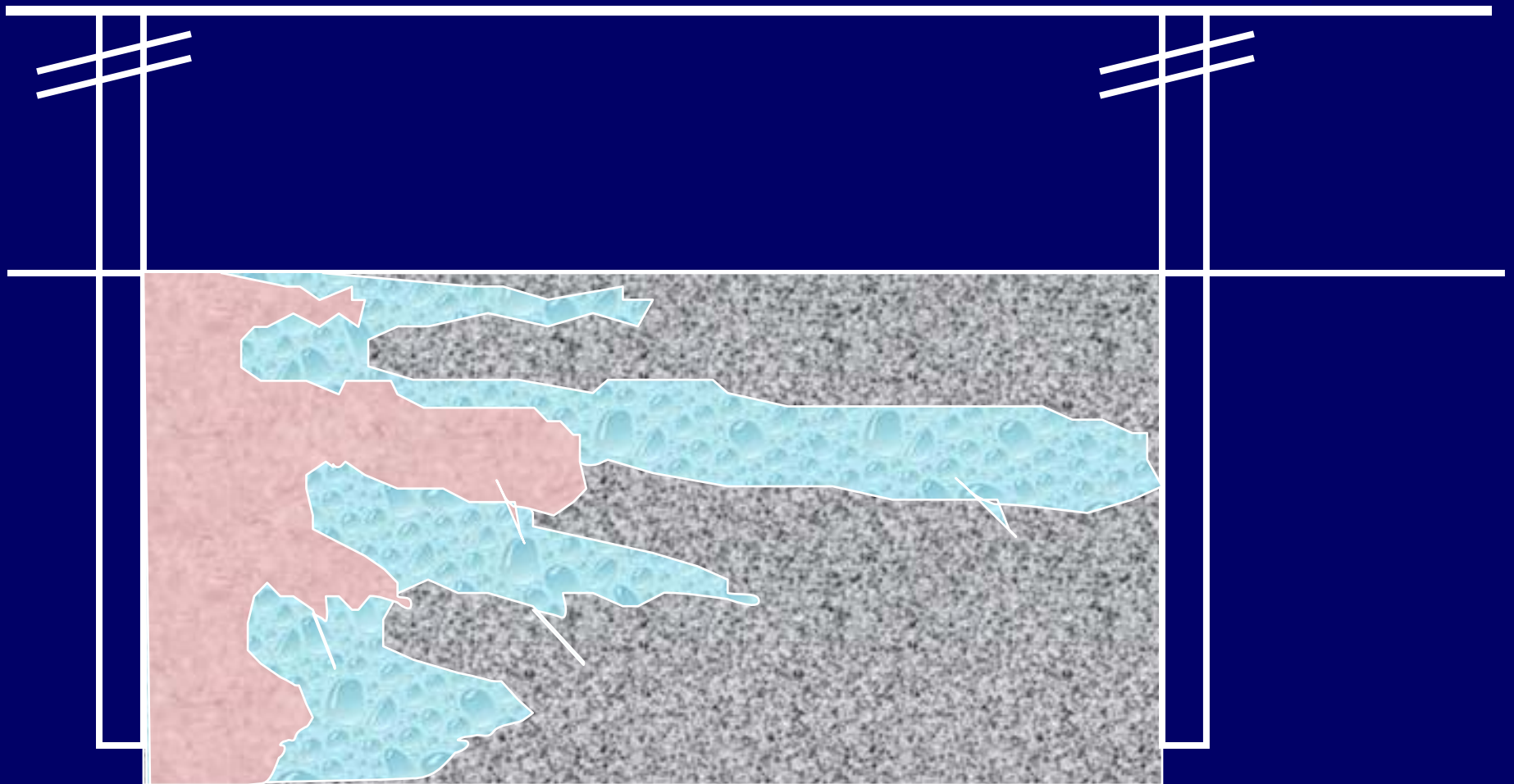
VISCOELASTIC SURFACTANT



Injector



Producer



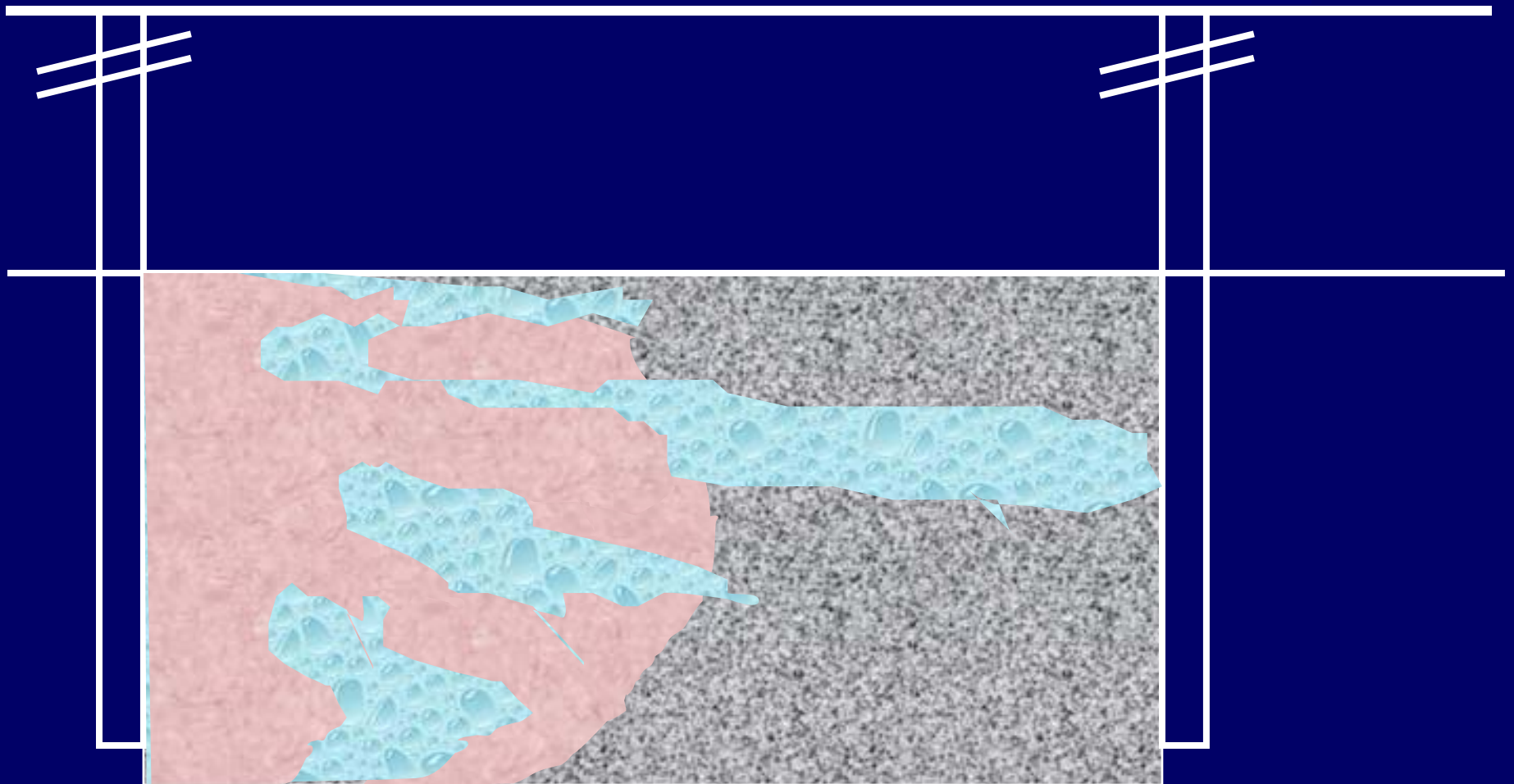
VISCOELASTIC SURFACTANT



Injector



Producer



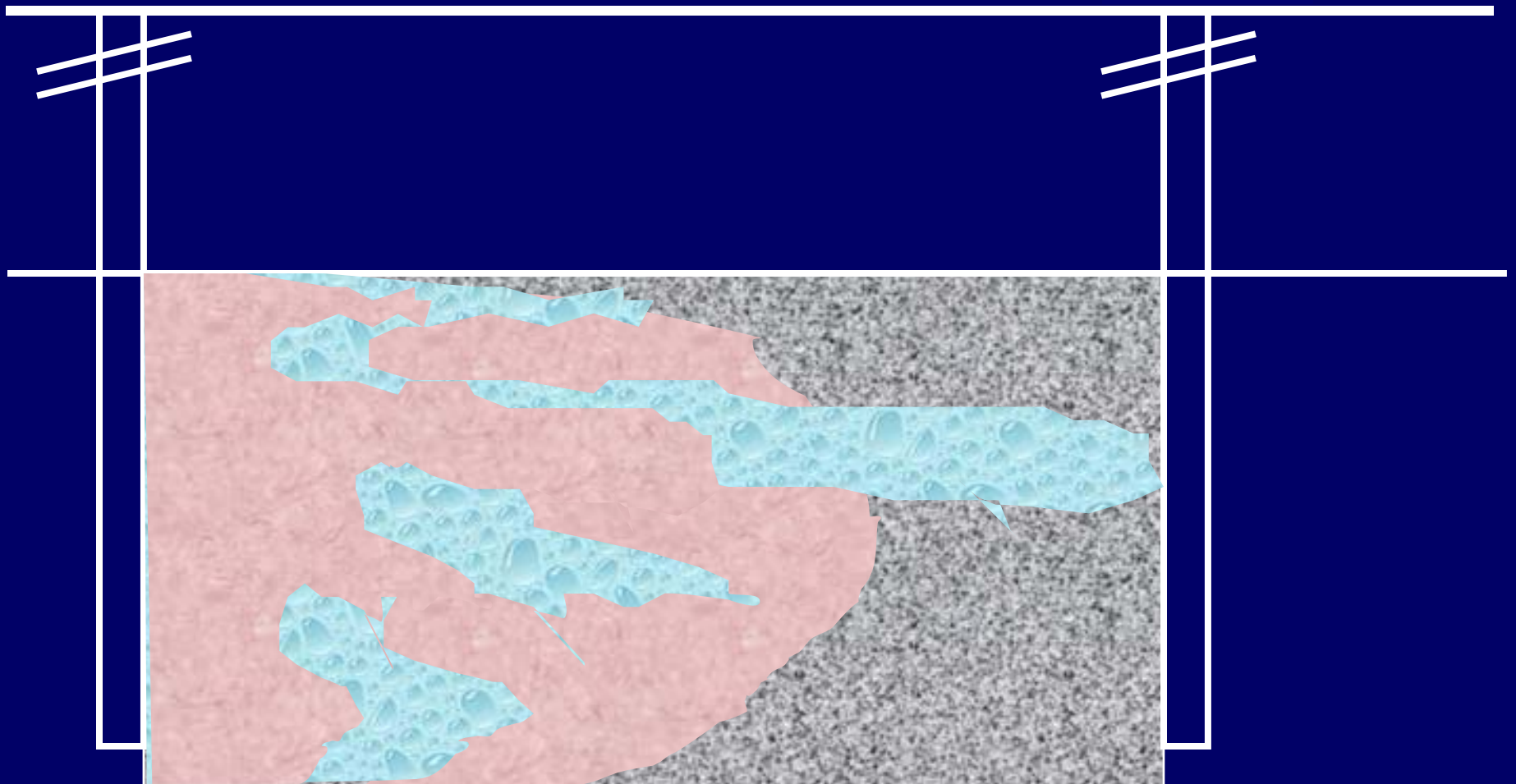
VISCOELASTIC SURFACTANT



Injector



Producer



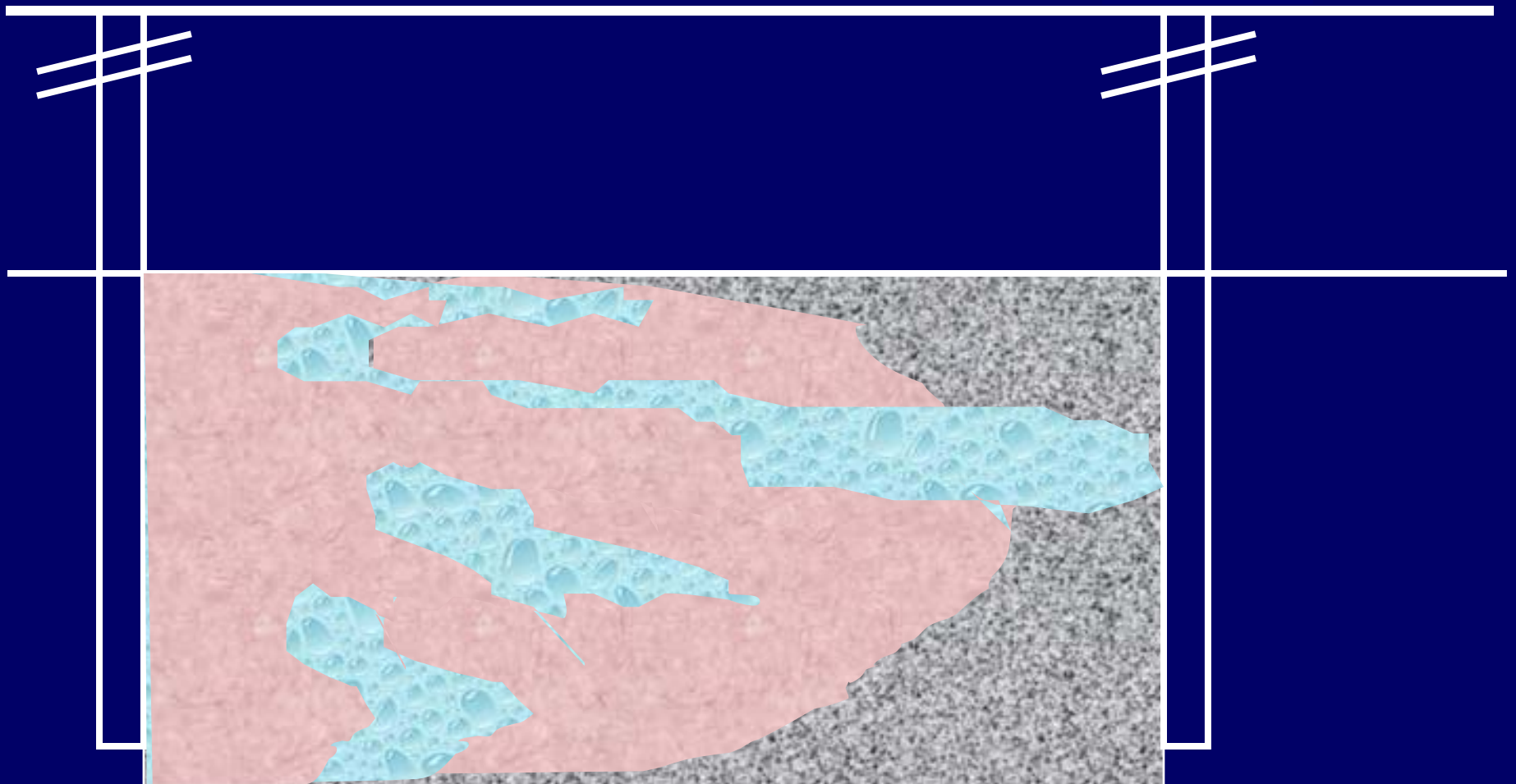
VISCOELASTIC SURFACTANT



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Producer



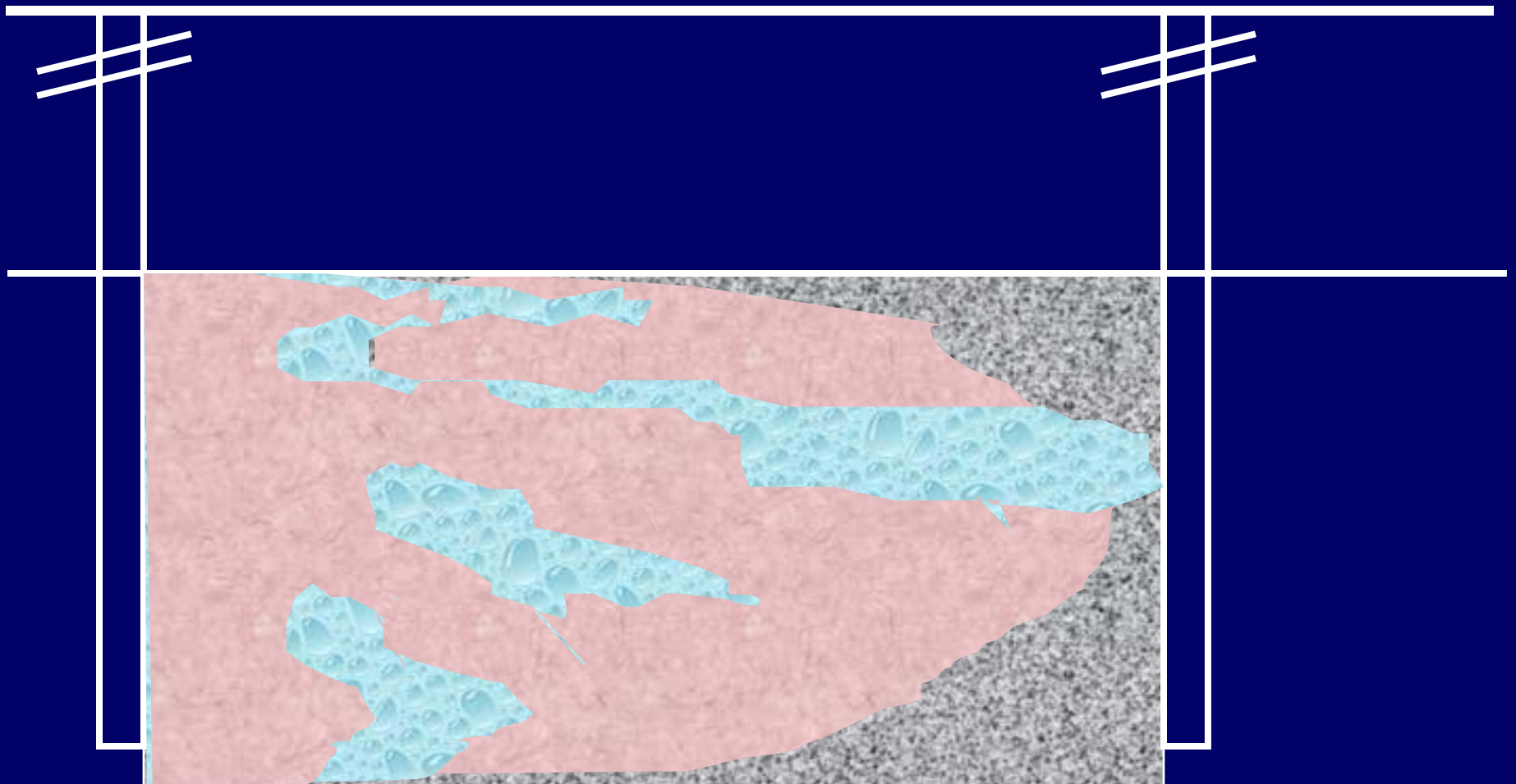
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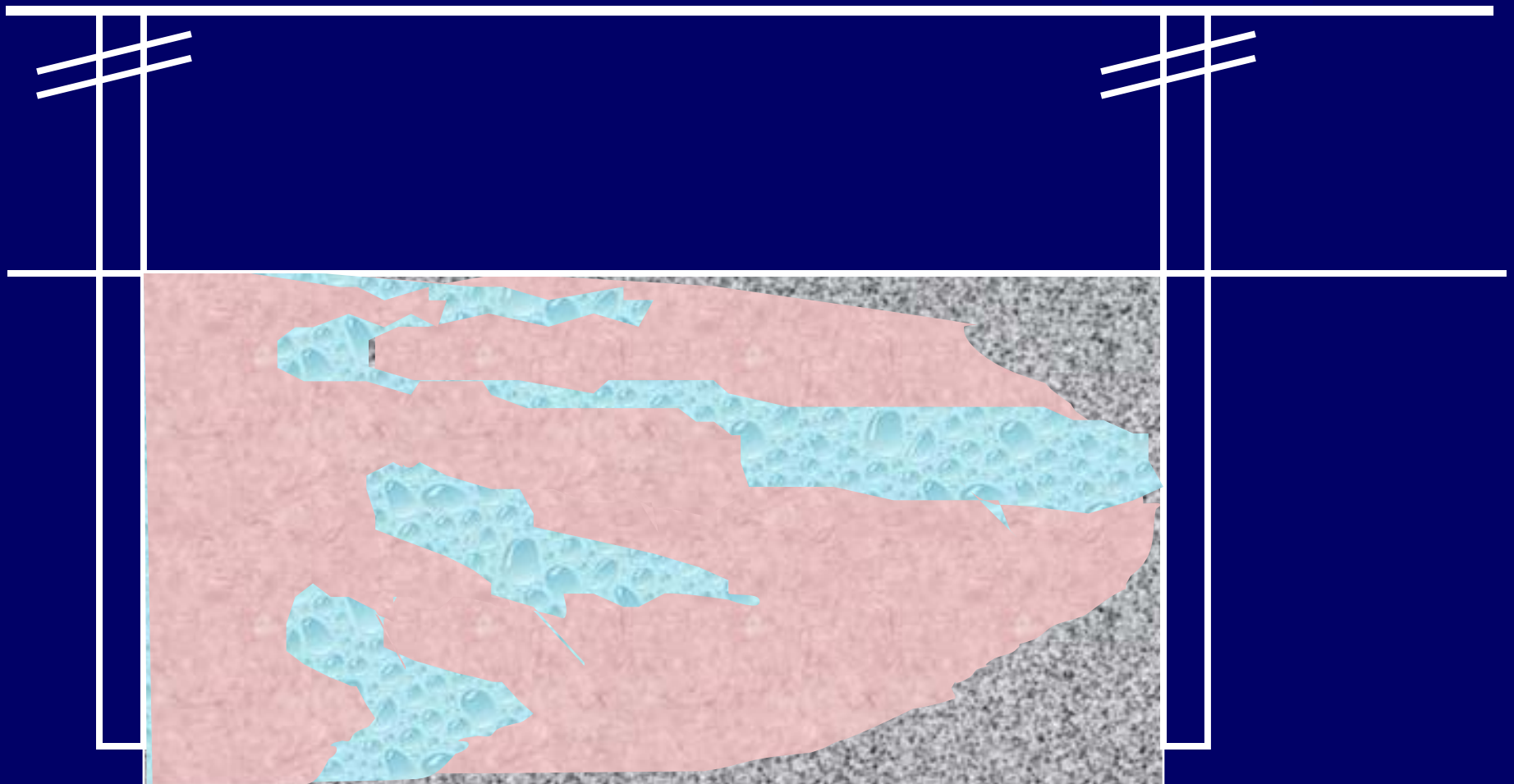
VISCOELASTIC SURFACTANT



Injector



Producer



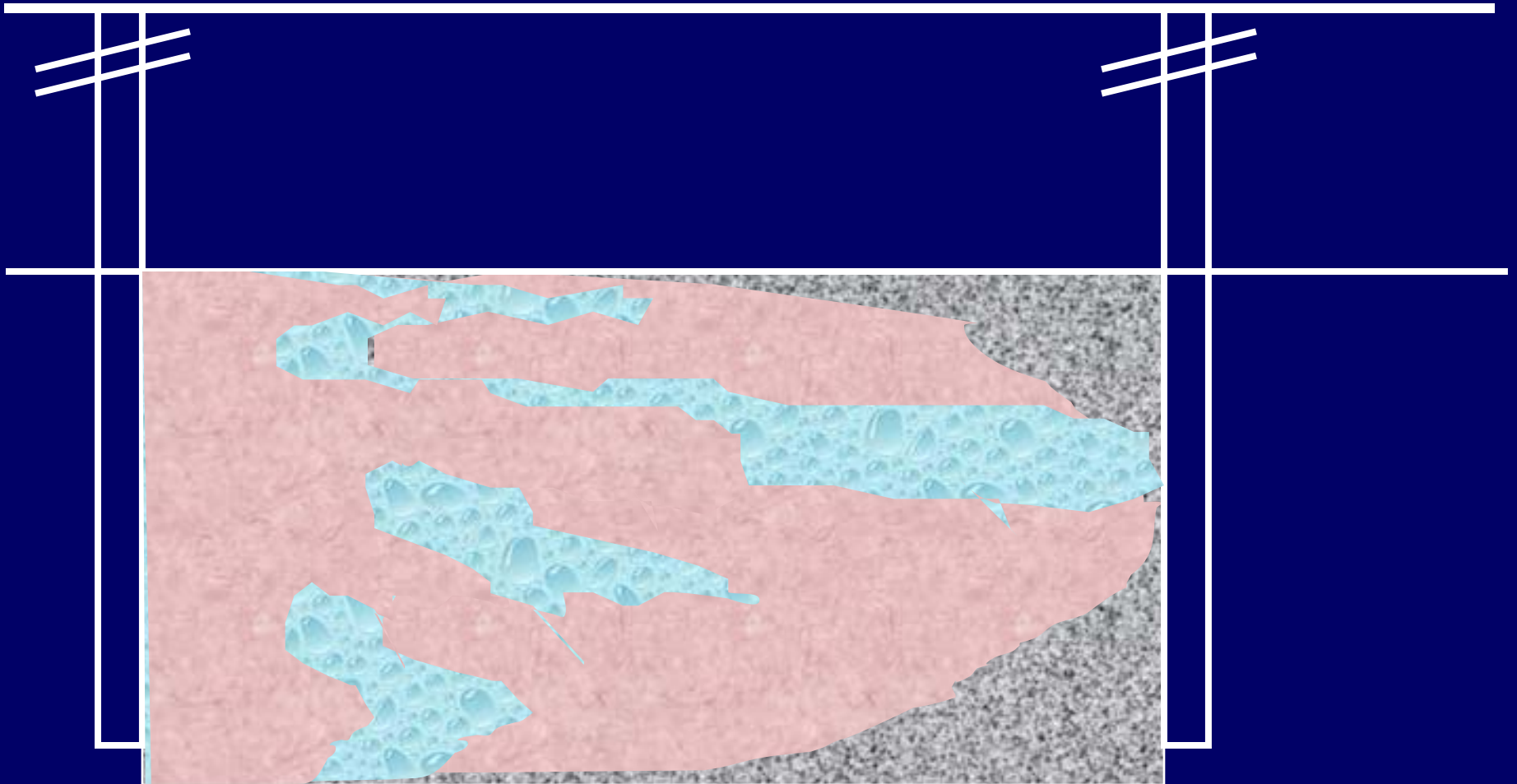
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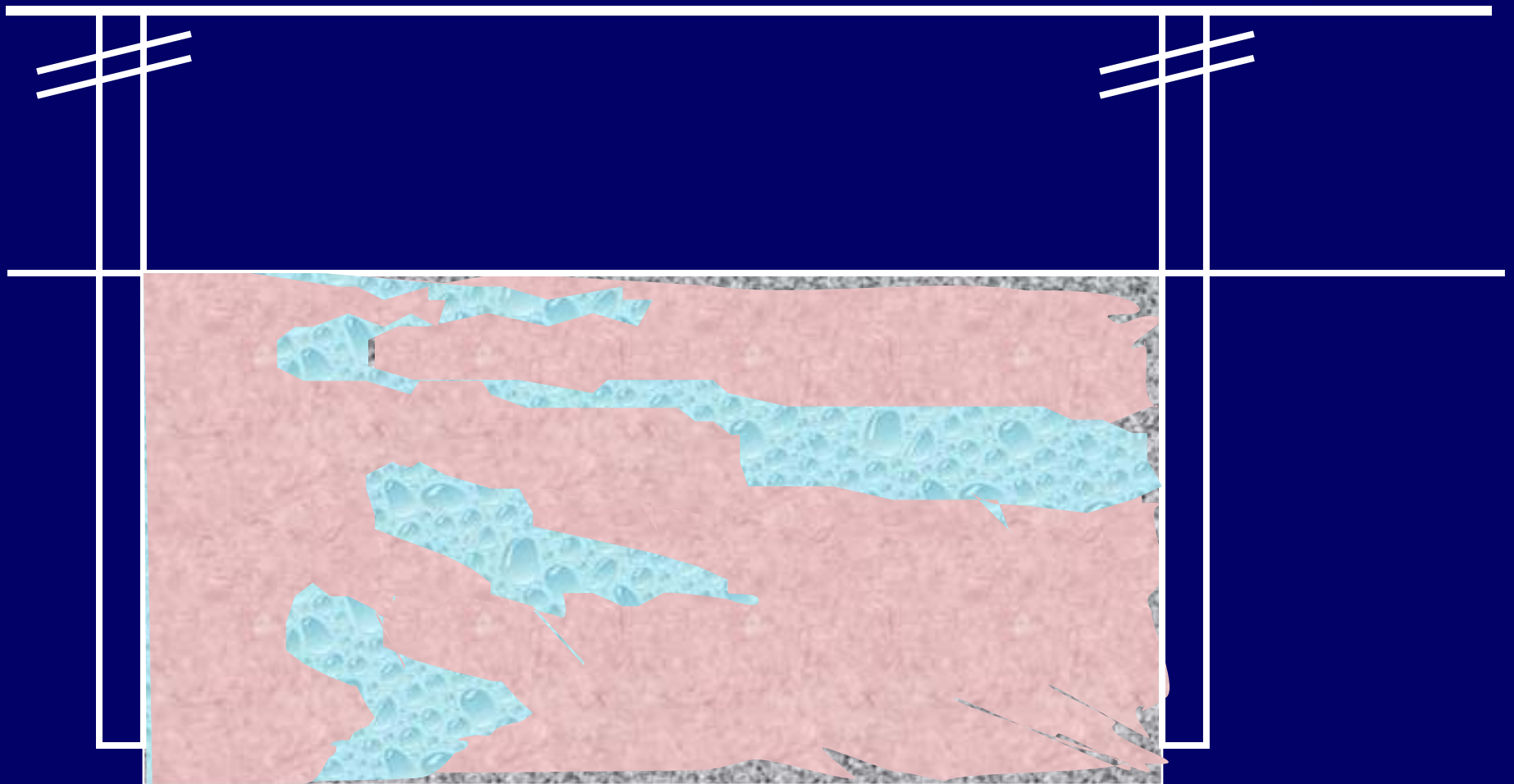
VISCOELASTIC SURFACTANT



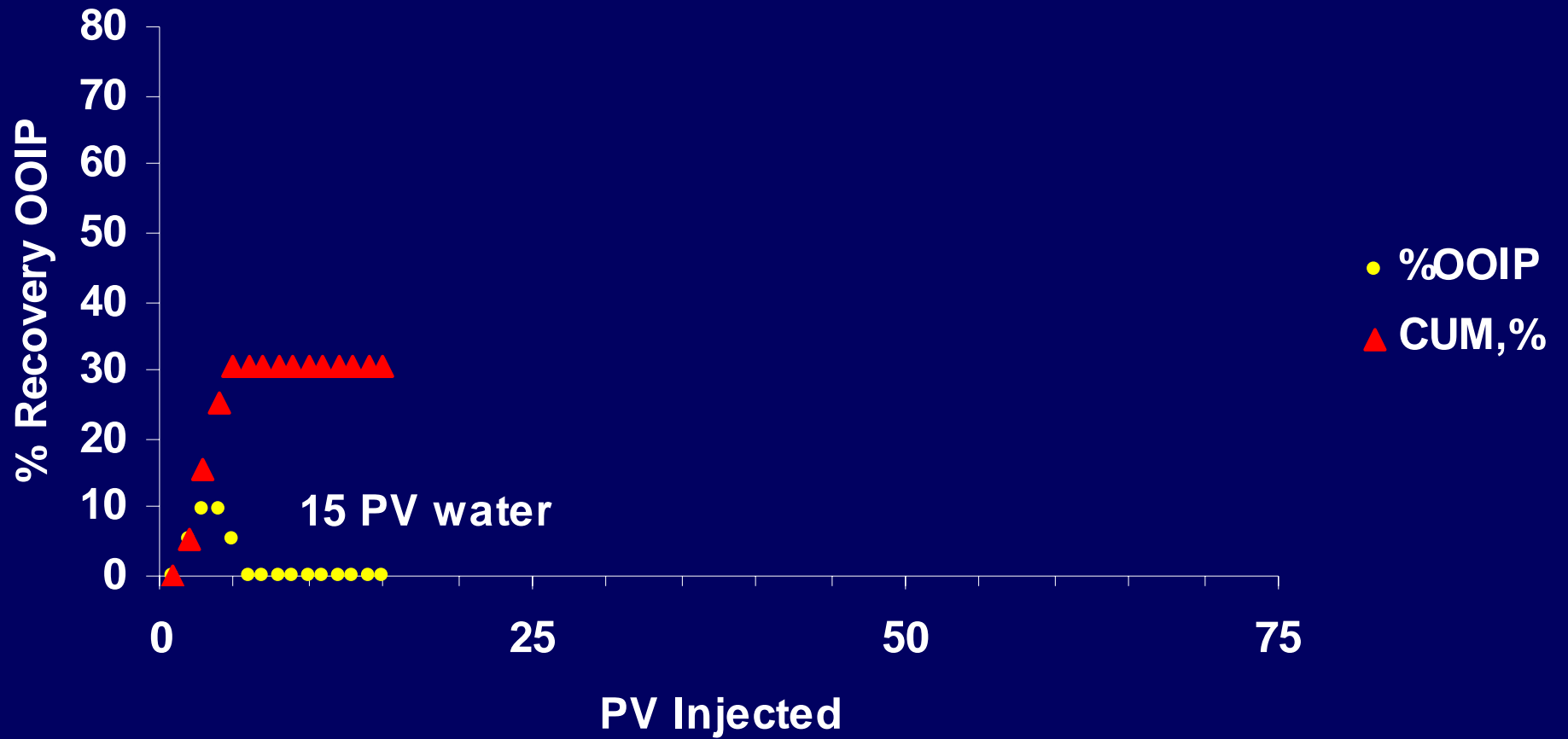
Injector



Producer

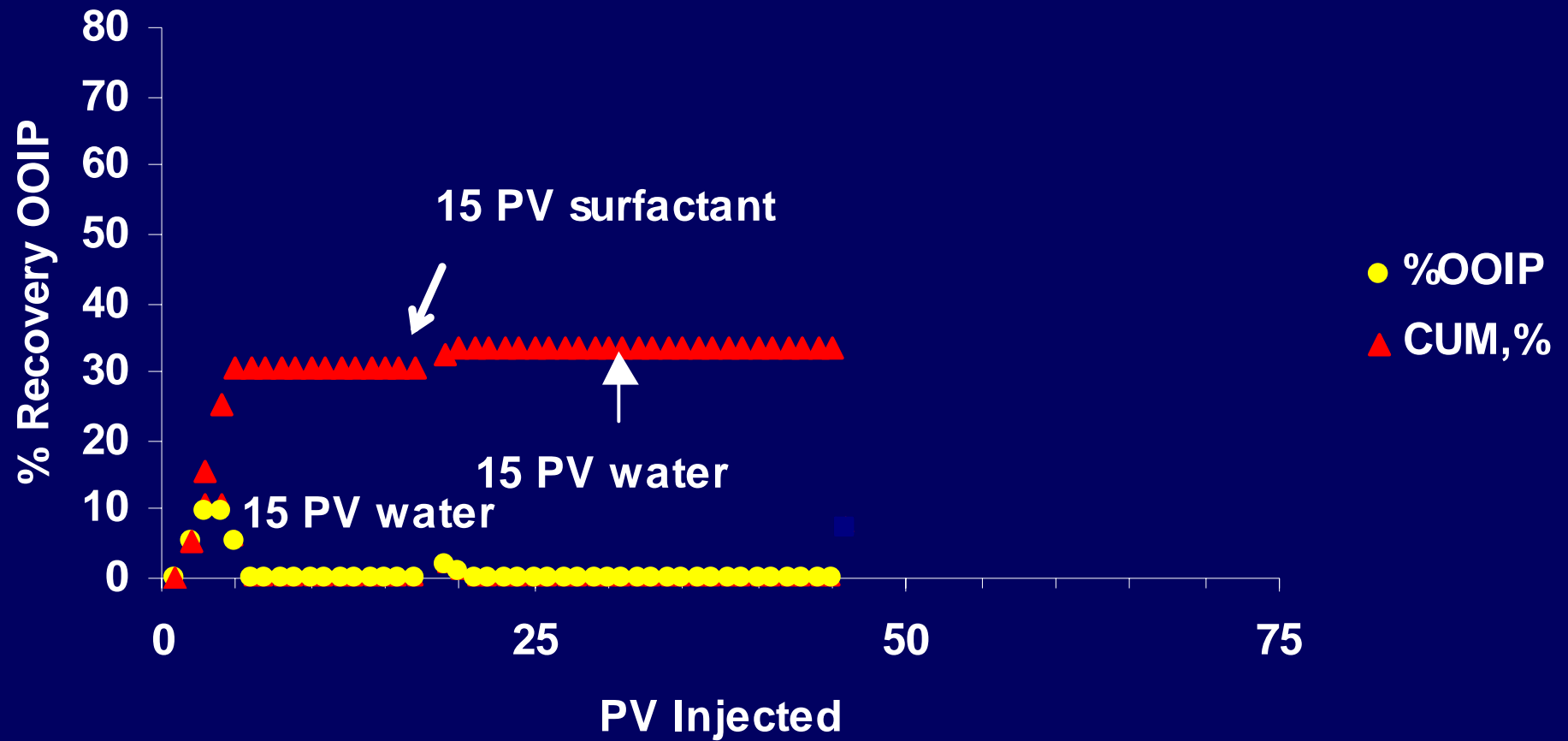


35000 TDS, 1700 Ca/Mg
0.1% surfactant
0.6% smart surfactant

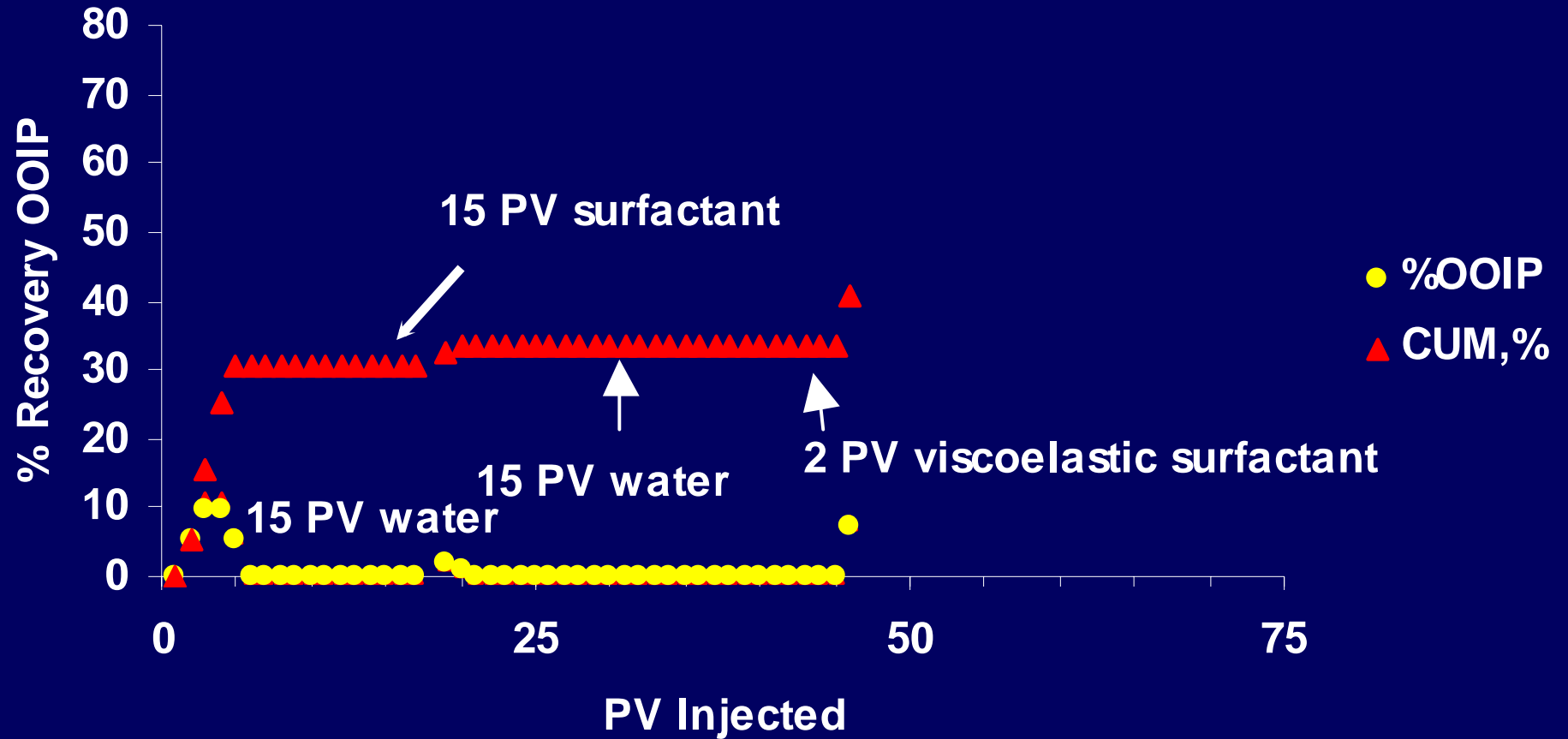


US PATENT 7,373,977

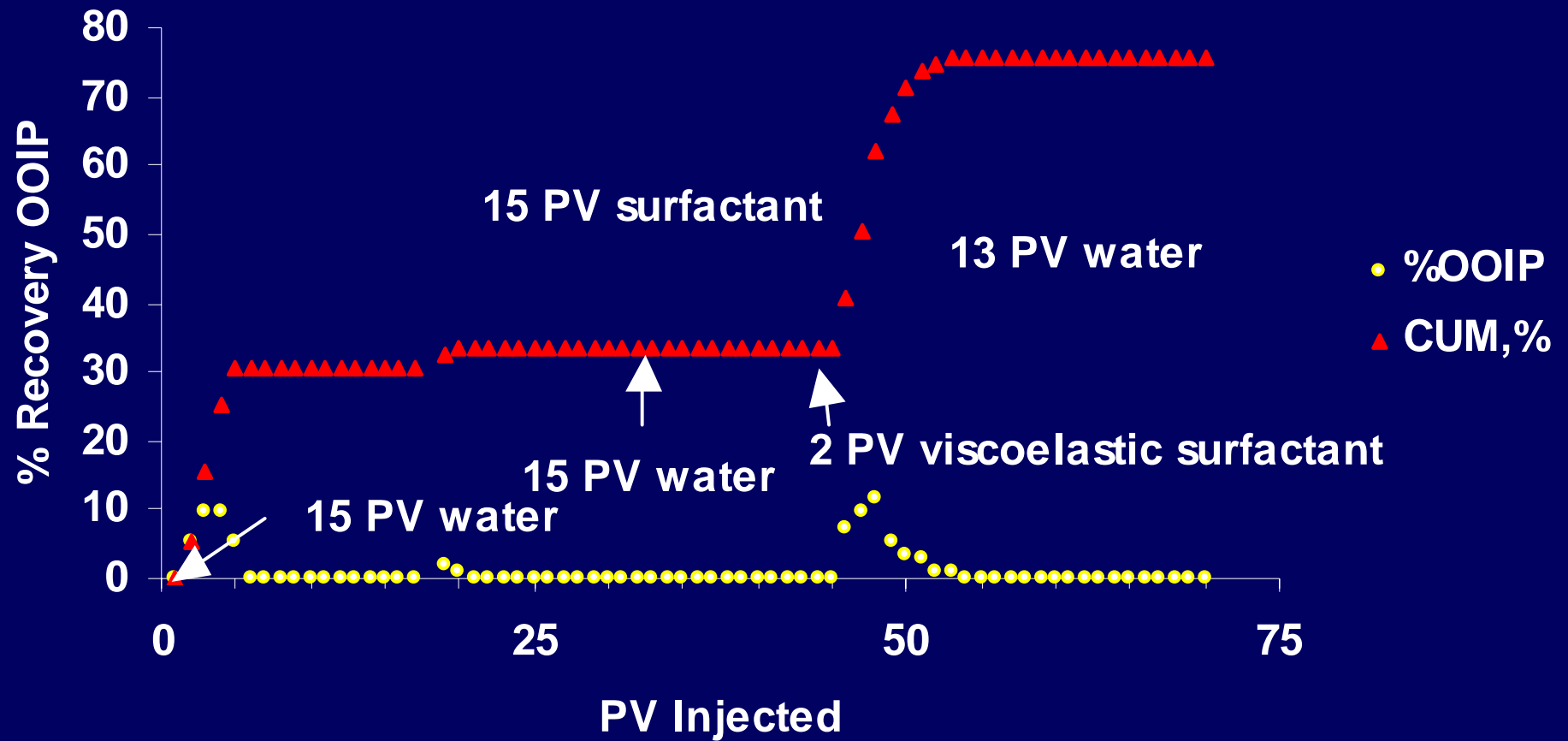
35000 TDS, 1700 Ca/Mg
0.1% surfactant
0.6% smart surfactant



35000 TDS, 1700 Ca/Mg
0.1% surfactant
0.6% viscoelastic surfactant



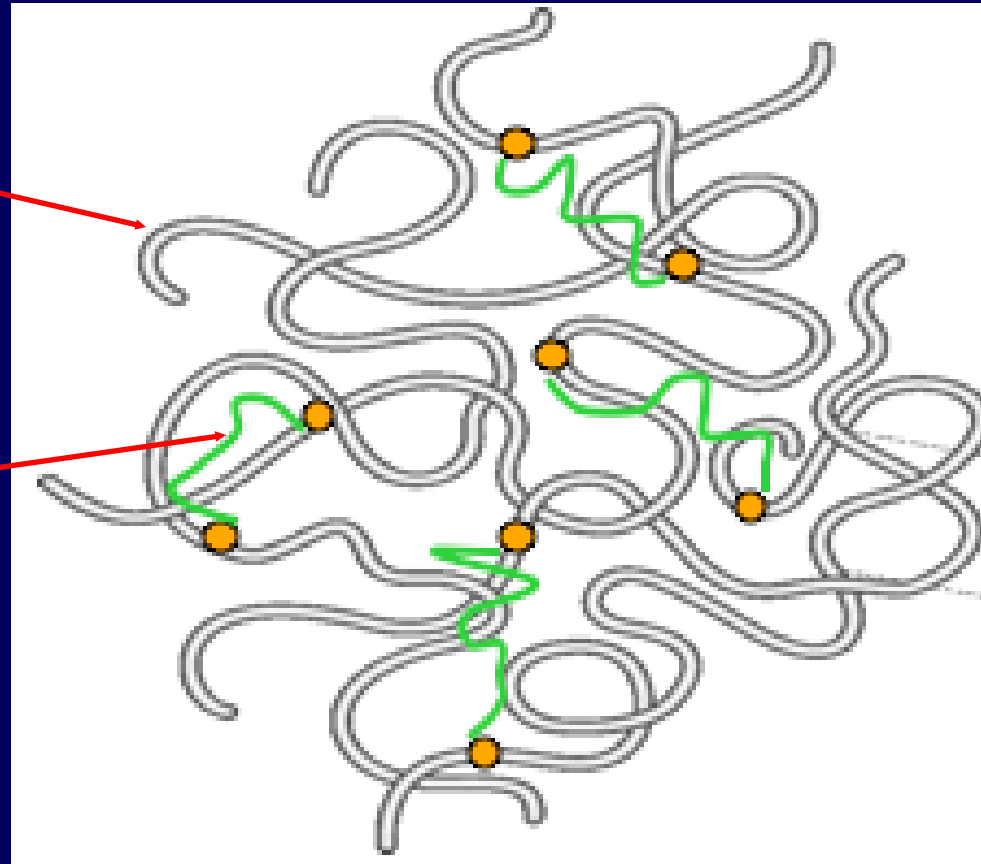
35000 TDS, 1700 Ca/Mg
0.1% surfactant
0.6% viscoelastic surfactant



VISCOELASTIC SURFACTANT STRUCTURE

Work-like viscoelastic surfactant micelles for viscosity

Cosurfactant for low IFT

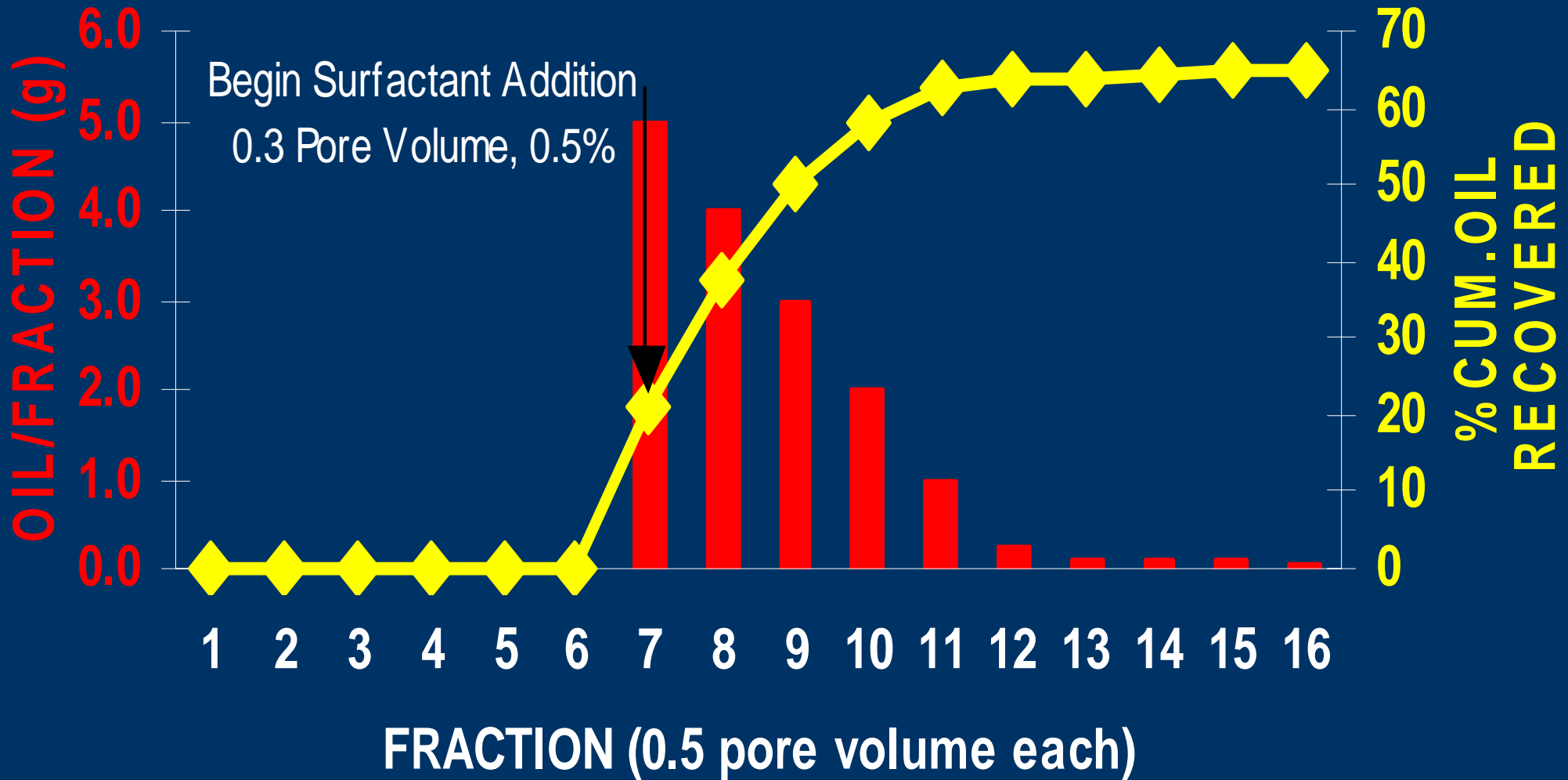


APPLICATION OF VISCOELASTIC SURFACTANTS

- **Viscoelastic Surfactants Alone –**
 - **Tight formations, high temperatures, high salinities**
- **Viscoelastic Surfactants With Polymers -**
 - **High viscosity oils, polymer gives residual viscosity when contacting oil**

US PATENT 7,373,977

RESIDUAL OIL RECOVERY TEST



APPLICATION OF VISCOELASTIC SURFACTANTS

- **Viscoelastic Surfactants Alone –**
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 - **High viscosity oils, polymer gives residual viscosity when contacting oil**

US PATENT 7,373,977

VISCOELASTIC SURFACTANT WITH POLYMER IN SEA WATER

	Description	IFT,mN/m	Visc, cps
A	0.05% anionic surfactant	Ppt	Ppt
B	0.45% viscoelastic	0.092	62
C	A+B before oil contact		81
D	A+B after oil contact	0.0042	2.7
E	0.010% polyacrylamide	2.8	10
F	C+E		90
G	D+E	0.0051	11

CONCLUSIONS

- **Viscoelastic surfactants have been developed that provide both low IFT and high viscosity in injection fluids**
- **Unlike polymers, viscoelastic surfactants are not permanently degraded by high shear.**
- **Also, unlike polymers their viscosity building characteristics are not reduced by high electrolyte concentrations.**
- **Viscoelastic systems can be designed to tolerate both high temperature and high salinity conditions.**

THANK YOU !

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